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Abbreviations. — D. = Discussion; I. = Illustrated.
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THE NORTHERN BOUNDARY OF MASSACHUSETTS.

BY NELSON SPOFFORD, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society December 21, 1904.]

BY way of preface a brief history of the New Hampshire boundary and the controversy with Massachusetts may not be out of place, this matter having been a subject of contention ever since the first settlement of the country. Volumes would be required to contain a small part of what has been written on this subject; consequently we must omit much early history, and take up the year 1740. Upon the basis of the old charter that gave to the colony of Massachusetts Bay all the land between a line 3 miles south of the Charles River and 3 miles north of the Merrimack River, Massachusetts had persisted in the claim to 3 miles north of every part of the Merrimack River, and had chartered towns as far north as Concord, N. H. New Hampshire had disputed that claim on the ground that when that charter was granted the Merrimack River was supposed to run about due east for its entire length; and New Hampshire claimed for her southern boundary a straight line, due west from a point 3 miles north of the mouth of the Merrimack River. One John Tomlinson and his assistant managed New Hampshire's case before the King's Council; and a decree was made bearing date of August 5, 1740, in the following words:

"That the northern boundaries of the province of Massachusetts Bay are and be a similar curved line, pursuing the course of the Merrimack River, at 3 miles distance on the north side thereof, beginning at the Atlantic Ocean, and ending at a point, due north of a place, in the plan returned by the com-

missioner, called Pautucket Falls, and a straight line drawn from thence due west, across said river, till it meets his Majesty's other governments."

This line crossed the Merrimack River about 12 miles further south than the line claimed by New Hampshire, and cut from the jurisdiction of Massachusetts 16 townships and transferred them to the jurisdiction of New Hampshire. It is needless to remark that Massachusetts was astounded at this result of referring the case to the King in Council, and New Hampshire was equally elated at the victory thus obtained. No effort was spared on the part of Massachusetts to have this decree annulled or amended, but all to no purpose. New Hampshire immediately took possession of this territory that had been under the jurisdiction of Massachusetts for more than a hundred years, while Governor Belcher was ordered to have the line run in accordance with the decree (on pain of dismissal from his office if the work was neglected), and the work was executed on the ground, March and April, 1741. George Mitchell, of Portsmouth, N. H., was appointed by Governor Belcher to run the curved line opposite and 3 miles north of the Merrimack River, from the ocean to Pawtucket Falls. Richard Hazen, of Haverhill, Mass., was appointed to run the due west line, but Massachusetts took no part in that work, and New Hampshire paid all the bills, Belcher being governor of both provinces at that time.

The lineal descendants of Richard Hazen are still living in Hampstead, N. H., and a copy of the diary that Hazen kept on that work was obtained from one of them a few years ago and is now on file at the State Treasurer's office at Concord. It has been printed in New Hampshire state papers, but has never been printed by the Commonwealth of Massachusetts, although Richard Hazen was a Massachusetts man to all intents and purposes. The writer first saw it in the *New England Historical and Genealogical Register* for July, 1879, page 323. A few passages somewhat abridged and "edited" will serve to exhibit the character of the work.

"Friday, March 20, 1740. At eight o'clock, forenoon, we set out from my dwelling house in Haverhill with our provisions on small hand sleds which we hauled up the Merrimack River with great difficulty and danger of falling through, most of the falls in the river being broke open and in other places the ice was thin and very rotten, and at eight o'clock at night we came to Mr. Richard Hall's at Tewksbury and lodged by his fireside.

"Saturday, March 21. At break of day we went from Mr. Hall's and passed over Concord River on the ice without any apparent danger, notwithstanding it was open a little above us and below, and at nine o'clock, forenoon, we came to Colonel Varnum's where about ten o'clock George Mitchell, Esq., and company, who had been taking the bends of Merrimack River from the sea in order to run similar lines in a proper season for it, also arrived, and the colonel, having very generously dined both companies at his own expense and cost and concluded at what part of the falls to begin to measure a due north line (the place concluded on being directly opposite to Tyng's saw mill and called the Great Bunt).

"The said Mitchell set forward on his course, and measured the said 3 miles which ended about 14 poles southerly of Colburn's old meadow and near the easterly end of it, where the said Mitchell caused a pitch pine to be marked and lettered with (M) on the southerly side for the mark of the Massachusetts Bay; and (N. H.) for New Hampshire, on the opposite side, and erected a pillar of stones round the same tree, and then we parted, the said Mitchell returning home, and I set forward on my course from said pine tree, a course due west according to my instructions, that is west ten degrees north, variation allowed per order of the governor and council; and the same night I measured 1 mile and 16 poles to Beaver River.

"Wednesday, April 15. We measured 6 miles and lodged on the bare ground. At the end of two miles we crossed a large stream running southwesterly. At the end of another mile we crossed the same stream, and 80 poles before we finished this day's measure we waded through a swamp almost to our middles in water.

"April 16 we measured to Hudson's River. On a small mountain 4 miles from where we began to measure we had a fair view of the city of Albany and at the same time had as fair a view of the falls of Mohawk River called Cohoos or Great Falls, above Albany, to our very great joy, and we named the hill Mount Joy, the said falls being distant from us 3 or 4 miles; from there we kept our course to Hudson's River at about 80 poles from the place where Mohawk River comes into Hudson's River. We went thence to Albany and tarried there that night. . . .

"We kept on our course until April 26.

"I purchased a canoe at Dunstable and we came down the Merrimack River to our homes where we arrived about nine o'clock after 37 days' journey, all in perfect health through God's great goodness to us."

Hazen's party numbered 8 men all told. Where is the engineer or party to-day that would undertake the task that lay before these men that twenty-third day of March, 1741, when they bade good-by to George Mitchell and his party at Boundary Pine? Their task was to run a straight line nearly 120 miles long, with an ordinary surveyor's compass, a rude instrument at

that, probably, 50 miles of the distance through an unbroken forest from the Connecticut River to Hudson River, and only partly settled from Boundary Pine to the Connecticut River; yet they accomplished this work in 5 days less than one month.

In Governor Belcher's warrant to Richard Hazen, we find the following words:

"And you are to take especial care in this your survey, that you faithfully spot the trees, standing in the said line, and make the best monuments you can besides."

Hazen in his report says that "owing to the snow he could make but few monuments," but spotted trees are good for a hundred years. When we made the preliminary survey of the Hazen line in 1891, we found an old pine tree lying partly down the west bank of the Merrimack River; on interviewing the owner of the land, Frank Bancroft, we found that this tree was the identical pine that Richard Hazen's men spotted on the twenty-third day of March, 1741. Mr. Bancroft informed us that it was standing and leaved out only three years before. There is no doubt about the correctness of the tradition.

The most careful inquiry failed to show that the location of the boundary of 1741 had ever been litigated in the courts of either state. Copies of Hazen's and Mitchell's maps were among the documents received from England in 1887, and we had them photographed for the Massachusetts Commissioners' Report of 1889.

Mitchell's work seems to have been fully as successful as Hazen's. We made a plat of our work on the same scale as Mitchell's map, and then made a tracing of our map. On applying this tracing to the Mitchell map, they were found to coincide with astonishing exactness, only a slight variation at Bradford neck being apparent. From the ocean to Boundary Pine is about 36 miles as the river runs; the area of the territory north of the river should then be 36 by 3-108 sq. miles. After completing our map of the river and boundary line on a scale of 2 500 ft. to an inch, we made a very careful estimate of the area between the north shore of the river and the line of the monuments, and we found 104 sq. miles in round numbers. Then we went over Professor Quimby's map in the same manner, the two measurements agreeing very nearly, and thus we demonstrated the accuracy of Mitchell's map in another way. Our map probably cost nearly, if not quite, a thousand dollars, but it is doubtful if Mitchell received a hundred for his work.

We come now to a brief consideration of the re-survey of the

New Hampshire line in 1825. It appears from the records that commissioners were appointed by both states to perambulate the line. Caleb Butler, of Groton, was appointed surveyor for Massachusetts, and Eliphalet Hunt, Esq., was appointed surveyor for New Hampshire. In the month of August, 1825, the commissioners with the surveyors met at Salisbury Beach, and retraced the Mitchell line and the Hazen line to Connecticut River. The commissioners for both states reported that they had found the Mitchell and Hazen lines substantially as they were run and marked in 1741. At a subsequent meeting of the commissioners the surveyors presented a protraction of the line run by Richard Hazen. It appeared from this plan and other statements made in the interest of New Hampshire that this line crossed the Connecticut River nearly 3 miles north of a point due west from Boundary Pine. The commissioners on the part of New Hampshire then proposed to the commissioners on the part of Massachusetts to run a new line in conformity to the original decree; but this proposition was peremptorily declined, our commissioners stating that they were only authorized to retrace the line of 1741. This difference parted the two commissions, and they never met afterwards. In 1827 the Hon. Benj. F. Varnum, of Dracut, who was Butler's assistant surveyor two years before, was ordered to erect the monuments on the Hazen and Mitchell lines, one at each Massachusetts town corner and one at each angle in the Mitchell line, marked "M S" on the south side.

At a point near Captain's Pond, in Salem, N. H., we found two monuments about 400 ft. apart, on the course from said pond to the northwest corner of Haverhill, and this fact led to our connection with the Massachusetts northern boundary survey. In order to solve the problem of these two monuments we went to the state records of Massachusetts. We found the reports of the Massachusetts and New Hampshire commissions of 1825 all on file and Butler's maps of the Mitchell line and the Hazen line. The two reports of 1825 showed conclusively that no boundary line between Massachusetts and New Hampshire had ever been established by the joint action of the two states. The facts being reported to the Haverhill city government, a petition to have the monuments recognized by both states was submitted to the Massachusetts legislature of 1883, but this was a failure. At the session of 1885 the Massachusetts legislature passed resolutions authorizing the governor, with the advice and consent of the council, to appoint three commissioners, to meet a

like commission to be appointed by New Hampshire to ascertain and establish the true jurisdictional line between the two states, and repealing all previous legislation inconsistent herewith. This proposition was accepted by New Hampshire, and John J. Bell, of Exeter; Nathaniel H. Clark, of Plaistow; and Col. Charles Roberts, of Concord, were appointed on the New Hampshire commission. October, 1885, Governor Robinson appointed Henry Carter, of Bradford; Geo. W. Cate, of Amesbury; and Nelson Spofford, of Haverhill, commissioners for the Commonwealth of Massachusetts. The first meeting of the joint commission was held in Boston, November 7, and the second meeting at my office in Haverhill, November 21.

The Massachusetts commissioners had assumed that, the line having been marked by the Varnum monuments since 1827, all that would be necessary would be to run the lines on the ground, between the monuments, and mark the road crossings, but they soon found that the old contest of 1825 was to be fought over again.

Mr. Bell's grandfather, Samuel Bell, having been chairman of that commission, the grandson must now follow in the footsteps of his predecessor, and he opened the controversy with the statement that the old king's decree of 1740 was just as valid and binding now as the day it was issued; that there was not then and never had been any legal boundary between the two states; that the decree of King George called for a line 3 miles north of the Merrimack River from the ocean to Boundary Pine, thence in a due west line to his Majesty's other governments; that Varnum set his monuments anywhere that he could dump them by a road side; that instead of being 3 miles from the river some were only 2 miles and some were about 4 miles; that the line from Boundary Pine to the Connecticut River crossed that river 3 miles too far north, taking from New Hampshire a large gore of land 58 miles in length averaging 1.5 miles in width; that consequently we must commence *de novo*, run a new line 3 miles north of the river, and a due west line to the Connecticut River from Boundary Pine.

Replying to this harangue the Massachusetts commissioners informed Mr. Bell that the old decree of 1740 was not worth the paper it was written on; that King George closed his real estate office in Massachusetts, June 17, 1775, and had done no business here since that date; that Governor Belcher appointed George Mitchell and Richard Hazen, under oath, to mark out the line on the ground, in accordance with the decree; that the work was

duly executed and accepted by Governor Belcher, the maps properly returned to the authorities that issued the decree, accepted and recorded, and the bills for that work had all been paid by New Hampshire, which then signified its acceptance of the work, and that the line thus accepted and recorded had been recognized as the line of jurisdiction by both states for the space of 140 years; that their work had been reviewed in 1825 by commissions authorized by both states, and both had reported that the original lines had been found, and that two years later, 1827, Hon. Benj. F. Varnum had been commissioned by the legislature of Massachusetts to erect the monuments on said lines; that the monuments as standing marked the line between the two states and that there the line must remain.

This question was argued pro and con from 10 A.M. to 9 P.M., and an agreement was finally reached to get the best available map of the Merrimack River and to survey the line as marked by the monuments from Boundary Pine to the ocean.

Shortly after, the writer resigned his commission and was appointed surveyor for Massachusetts, and Col George Whitney, of Royalston, was appointed commissioner to fill the vacancy.

Prof. E. T. Quimby, of Hanover, was appointed by the New Hampshire commissioners as surveyor for that state. He was to determine the distance of each monument from some point on the river by triangulation. With his assistant he camped at Reservoir Hill in Lowell, about the first of May, 1886, and went through to the ocean.

The Massachusetts party was to survey the boundary line by course and distance from monument to monument. At the commencement of our work the problem that presented itself was to run straight lines from monument to monument, nearly the entire distance being covered with tall pine trees, and to do it without the use of random lines. In the practical execution of that survey, we did some things not laid down in any treatise on surveying. As to how we accomplished this, we beg leave to refer engineers to our contributions to *Engineering Record*, December 10, 1904, also to our article on "Daytime Observations on the North Star," October 22, 1904, by which we determined the true course of every line from Boundary Pine to the ocean, and finally to our article in that paper, on "Steel Tape Measurements," published July 16, 1904. These three articles in the *Engineering Record* give the reader a pretty clear account of the field work of the survey.

Professor Quimby was stricken with paralysis December 17,

1887, and died February, 1890. Geo. W. Fernald, one of Professor Quimby's assistants in 1886, was then appointed surveyor for New Hampshire by the New Hampshire commissioners; but Mr. Fernald was taken sick soon after his appointment, and died without doing any work on the line. After the untimely death of Mr. Fernald, Ray T. Gile, of Littleton, was appointed surveyor for New Hampshire.

Previously to Mr. Gile's appointment the commissions of the two states had agreed upon the location of the eastern section and had agreed to make a preliminary survey of the western section. This survey had been commenced at Boundary Pine in October, 1890, but in consequence of Mr. Fernald's sickness the work was discontinued at Long Pond, October 18. It was resumed by the writer in company with Mr. Gile and two axmen at Long Pond, April 23, 1891, and continued through to the Connecticut River.

This survey developed the fact that there was no question about the line of jurisdiction; for, besides numerous monuments and wooden fences, we found 14 miles of solid stone wall, some of it 4 ft. thick, on the line of *jurisdiction*. Our instructions were to run our line as nearly as convenient to the line of jurisdiction, but not to follow it in any instance. We ran one straight line 21 miles, and the measurement came within 6 ft. of Borden's triangulation work. The measurements were all made with a 300 ft. steel tape, the contacts all being made on vertical plumb rods, kept in position by 2 assistants with stay rods.

This preliminary survey closed in August, Mr. Gile returning home, while our party immediately commenced setting the monuments on the eastern section. September 10, 1891, at 12 o'clock M., the joint commission met at Salisbury Beach to mark the extreme northern point of the Commonwealth of Massachusetts, and set the first monument ever placed on the Massachusetts and New Hampshire line by the joint action of the two states. This is a tablet on a ledge in the marsh, called "Major's Rock," where Simeon Borden set his copper bolt in 1836. The tablet is 3 ft. square and 1 ft. in thickness, with a circular conical opening through the center, showing the copper bolt just as he left it. The tablet was set in Portland cement, and secured to the ledge with 2 copper bolts 2 ft. in length leaded to the rock and to the tablet also. The tablet is made of New Westerly granite, polished on the top and west and south edges. There are some 400 letters and figures on the upper surface, and on the southerly edge letters and figures showing the latitude and longitude of this station.

Our party was occupied in setting the monuments from the 27th of August to the last of November in 1891. The Boundary Pine monument is 18 by 18 in. and 9 ft. long, set 4.5 ft. in the ground, cut from New Westerly granite, the same as the Major's Rock tablet, all four sides polished and lettered the same as the tablet, substantially, with the addition of the cut of a pitch-pine tree on the eastern face. All the other monuments, 63 in number, are of ordinary light-colored granite. Those at the angles in the line are 16 by 16 in. and 8.5 ft. long, set 4.5 ft. in the ground, while the road crossing monuments are 14 by 14 in. and the same length. Margins 2 in. wide are cut on the corners, and two opposite sides are hammered 2 ft. down from the top, and properly lettered.

In the work of surveying and monumenting the Mitchell line, no attempt was made to straighten any course, but we followed the resolve of 1885 to ascertain and establish the true jurisdictional line. At South Hampton, N. H., it appeared that the straight line between two adjacent monuments was not the line of jurisdiction. The straight line from monument to monument passed west of the dwelling house and outbuildings of Mrs. Rebecca Palmer, while the owners of this place had always been residents of South Hampton. Consequently we set a new monument, and thereby followed the line of jurisdiction.

On the line between Haverhill and Plaistow it appeared that a straight line from Lover's Lane to the Foot monument would pass directly through the dwelling house of Nathaniel H. Clark, of Plaistow, one of the New Hampshire commissioners, and would leave his residence in the city of Haverhill. But Mr. Clark didn't see it; he said the state line had always passed on the south side of his house, near a certain elm tree, and it must stay there, and we moved the Foot bound 150 ft. south so as not to disturb Mr. Clark.

These two cases disposed of, there was no other place where straight lines between monuments appeared to differ from the line of occupation, and at the close of our work, December 2, 1891, 36 miles of the Massachusetts northern boundary had been established and monumented, never to be questioned by any court thereafter, all the work of this section having been completed and ratified by both commissions during the lifetime of the original commissioners, although only one of the original commissioners signed the final report in 1899.

Coming now to the western section; after the death of Mr. Bell, which occurred August, 1893, Hon. J. G. Bellows, of Walpole,

was appointed to fill the vacancy, and during his administration the monuments were erected on the western section of the Hazen line. The new chairman of the New Hampshire commission and the surveyor caught the straight line fever and had it in the natural way. Let us see what they did. On page 24 of Commissioner Bellows' report, after rehearsing what the two commissions had separately conceded, he proceeds as follows: "The commissioners on the part of both states, for the purpose of arriving at a settlement of all disputes, agree on the present line of occupancy, as the boundary line between them." How could anything be expressed in the English language more clearly than this, exactly what the joint commission had been executing in the work of surveying and monumenting the eastern section? Then the agreement proceeds: "Said line to be ascertained and run as follows:" How? By the 14 miles of stone wall on the line of occupancy, and various fences and road monuments which had been recognized as the line of jurisdiction from the day that Hazen's men spotted the trees? Not at all. The next paragraph of their agreement read as follows: "This line to be ascertained and established by running straight lines between adjacent town corners." The principle upon which the surveyor and the joint commission had established the eastern section of the line was to be completely ignored on the western section. Instead of making the line of occupancy the boundary line as they had agreed, these savants were to run a new line from Boundary Pine to the Connecticut River. Notwithstanding that they were forcibly reminded that two states are not competent to change a state line, that that was the business of the United States Congress, they went ahead with their straight line scheme; and surveyor Gile went with the crowd.

Now witness the result. Not a mile of the 14 miles of stone wall is now on the line monumented, but a strip of neutral territory, from 0 to 250 ft. in width, extending in sections from Boundary Pine to Connecticut River, is left for a bone of contention. No taxes can be collected, nor can any criminal be arrested, on this neutral territory. No officer from Massachusetts can go north of the line established by this state. No officer from New Hampshire can come south of the line established by New Hampshire, no matter whether it is legal or illegal.

No state, county or town can repudiate its own work. It is at once and forever estopped from that. If the joint commission

had presented its correct work to Congress to be ratified and Congress had accepted it, then the line monuments would have become the legal boundary. As it is, the Hazen line is the only legal boundary, and the joint commissioners' line is bogus, null and void, although accepted by both states.

A brief consideration of the salient points in the Vermont boundary controversy will close this paper.

It had been discovered by the preliminary survey of the western section of the New Hampshire line that the monument originally marking the southwest corner of the New Hampshire line had been undermined by the freshets in the river, and the point was apparently lost, hence the necessity of a Vermont commission. At the October term of the Vermont legislature for 1892 commissioners were appointed to join with Massachusetts and New Hampshire in fixing the southwest corner of New Hampshire and the southeast corner of Vermont, and near the end of the session the governor appointed three lawyers on the commission, Kittredge Haskins, L. M. Reed and J. K. Batchelder, but delay seemed to be the order of exercises with this commission. They never met the other commissioners until July 28, 1893, then adjourned until August 10. At this meeting at Brattleboro, the Vermont commissioners presented Volny G. Barbour, professor of civil engineering, from the Vermont State University, as surveyor for Vermont.

A reconnoissance of the line was ordered to be executed by the surveyors, to commence August 20, when we met Professor Barbour at Taconic Inn. The next day, Monday, August 21, the late Surveyor Walker, of Williamstown, Mass., piloted us to the northwest corner of Massachusetts. Then we passed over the line as shown by Mr. Walker and others, until Friday, 6 P.M., when we returned to Brattleboro. At this meeting it was decided to make a triangulation survey of the existing monuments on the line, Professor Barbour's scheme. Thursday, September 5, we commenced the triangulation work at northwest corner and closed at South Vernon, Saturday, October 21.

I was well aware of the difficulties of the work before we commenced the survey. Our work was based on Borden's triangulation work of 1836. Professor Barbour adopted for his base line Borden's Greylock–Jilson, about 85 000 ft., or 16 miles. The Borden stations were all accessible; the difficulty was in locating the town corners from Borden's points. At one place to reach a corner we were obliged to run a traverse about 2 miles long including three base lines and a multiplicity of

angles and triangles. Professor Barbour made a brief report at a meeting of the commissioners in Boston, February 9, 1894. In this report he stated that the triangulation map was made to locate the fences and other marks along the supposed state line. Town corners were not mentioned at all, nor Borden's Leyden, nor his Jilson, while he took Borden's Greylock–Jilson, about 16 miles, for his base line for his triangulation survey in 1893.

This little diversion cost the state of Massachusetts some $3 000; and then, to cap the climax of absurdity, when the commissioners met at Brattleboro, June 20, 1894, it appeared that the Vermont commissioners and surveyor Barbour had caught the New Hampshire straight line fever. The Barbour town corner triangulation survey and our maps were relegated to innocuous desuetude, the Vermont commissioners having given Professor Barbour express direction not to locate any town corners, after thousands of dollars had been expended and about three months' time lost in the triangulation work inaugurated for the sole purpose of locating all the town corners. The Vermont scheme was to run a straight line from northwest corner to Jilson, 19.5 miles, thence to Belding, at Connecticut River, 20.5 miles, regardless of the line of jurisdiction. On mapping this scheme it appeared that the line from Jilson to Belding would pass some 1 200 ft. south of the residence of Geo. H. Phillips, Esq., of Colrain, Mass., transferring Mr. Phillips to Halifax, Vt. When the commissioners were informed that Mr. Phillips was not going to Halifax, commissioners or no commissioners, this ideal straight line had to be chopped up and made into 4 lines, northwest corner to South Jilson, 19.5 miles; South Jilson to Phillips, about 5.5 miles; Phillips to Leyden, about 6 miles; Leyden to Belding, about 9 miles.

The work of running these lines on the ground was not commenced until August, 1896. Professor Barbour claimed that he should run the line from northwest corner to South Jilson. Our party ran one continuous line from Belding to Jilson, 9 miles, cut it out, measured it with a 300 ft. steel tape and plumb rods, and located all the town corners, intersecting only one on the entire 20.5 miles. Professor Barbour intersected one old road crossing monument, and that was all. The work of erecting the monuments was commenced immediately after the close of running the line. Professor Barbour's party set the monuments on the 19.5 mile section, our party set them on the 20.5 mile line, all of light colored granite, 14 in. square and 8.5 ft. long.

September 9, Professor Barbour notified me at South Vernon that he would be ready to set the new monument at northwest corner the next day. We all met there the next day about 10 o'clock, the New York party coming later.

Borden had written in his daily journal, dated September 24, 1836, as follows:

"Morning rainy, employed in writing; afternoon cleared up, when we took the stone I had prepared for a monument to the corner of the state and erected it in the place where the post had formerly stood, finding some of the decayed post when digging.

"The stone which we erected is of marble, about 5 in. square, and appears above the surface of the ground about 2 ft."

At the 1897 session of the Massachusetts legislature a resolve was passed authorizing the Massachusetts Topographical Commission to join the New York state authorities in a review of the Massachusetts and New York boundaries. This resolve specified that the surveyors were to run and monument the true line between the territory under the jurisdiction of the Commonwealth of Massachusetts and that under the jurisdiction of the state of New York, but the surveyors thought that as the original line was straight it should be made straight now; so they ran one straight line 41 miles long from Alandar Mountain to the Vermont line. This new line failed to intersect the Massachusetts northwest corner monument, and then the Massachusetts commissioners discovered the astonishing fact that the northwest corner of Massachusetts had been in the wrong place for over 150 years. Here was a dilemma indeed; but these surveyors were equal to the emergency. They took up our Barbour monument, and moved it over the state line into the town of Petersburg, in the state of New York, so that when the Massachusetts and Vermont Commissioners undertook to fix their line, they commenced the description at this removed monument, and consequently, by the record now, the northern boundary of Massachusetts starts in New York state, and runs some 60 ft. before it intersects the northwest corner of Massachusetts. These parties justified their work on the plea that the northwest corner of Massachusetts had been in the wrong place over 100 years, and this plea was sanctioned by the Massachusetts commissioners, the very parties that had fought Bell from 1885 until he died in 1893, on the ground that the monuments marked the line.

The same doctrine was carried out by those two distinguished men, Daniel Webster and Lord Ashburton, in the

northeastern boundary dispute, where they found a monument near Rouse's Point about a mile out of line, but they didn't move it. Again, about 1879, New York and New Jersey reviewed their boundary; what was supposed to be a straight line 50 miles long was found to be deflected to the south, near the center of the line, 4 900 ft., but New Jersey didn't ask to have it relocated. Once more, at the same time, 1879, the New York and Pennsylvania line was reviewed, which was originally intended to be on the 42d parallel of latitude, but the reconnoissance showed that no part of it was on that parallel, and that hardly any three monuments were in the same straight line, these having been originally placed at the end of every mile. The commissioners for Pennsylvania wanted the line corrected, and placed on the 42d parallel, but the New York commissioners said nay.

This boundary line was fixed in 1787 by David Rittenhouse, the best surveyor, mechanician and astronomer there was in the whole world at that time, and the monuments that he caused to be erected had marked the line of jurisdiction between the two states from that hour. Consequently, whether straight or crooked, that line must remain the boundary between the two states, and there it is to-day.

When Mr. Bond, the New York State engineer, came before the New York legislature with his straight line, all monumented, the legislature didn't see it. It refused to go back on its own record, Mr. Bond had leave to withdraw, and the parties that his straight line transferred from New York to Massachusetts still vote in New York, and they will be pretty likely to remain there. What becomes of the Massachusetts record, with some 60 ft. of the northern boundary projecting over the state line into New York? This *faux pas* has been enacted and placed on record in our state archives. Must not this law be repealed and the whole record expunged? Owing to the removal of the Barbour monument, to-day there is not so much as a birch stake on the ground, to indicate the northwest corner of the state.

The Massachusetts commissioners, Messrs. Savage, Cate and Hodgdon, seem to have taken their cue from Professor Barbour, as on page 3 of their report, dated January 19, 1900, we find the following statements:

"No official monuments had ever been erected on the Vermont line, except at the northwest corner of Massachusetts a small stone had been placed in position, to mark the bound, and a Varnum monument on the west bank of the Connecticut River,

but there were no monuments between these two points. A state boundary line 41.5 miles long, that had limited jurisdiction for 150 years, had no marks on the ground, only at each end, and no question as to its location had ever been before the courts of either Massachusetts or Vermont."

How did we locate and map 15 town corners if there were no monuments on the line? We found 5 town corners and one road crossing marked with slatestone monuments from 1.5 to 3 ft. high, and stakes and stones and fences mark the others, and one road crossing was most emphatically marked by the northern end of Esquire Phillips's house.

No joint report on the Massachusetts and the Vermont line was ever written by the surveyors for those two states, and no map made by either of the surveyors was ever seen by the legislature of either state, and no map of the line was ever made by Professor Barbour.

A glance at any ordinary map of Massachusetts shows about 100 miles of the northern boundary as an absolutely straight line. In the last half of Professor Barbour's report he goes into a lengthy dissertation on his straight-line scheme, asserting that a straight course from Boundary Pine to northwest corner would cross Connecticut River 300 ft. south of Belding, the point where Hazen crossed in 1741, but upon applying a straight edge to Borden's large map the fallacy of this statement was apparent. Borden had no less than 7 of his triangulation stations from Boundary Pine to northwest corner with their positions all determined by that master of mathematics, and all of them but Boundary Pine on high ground. But having all the measurements and courses from the true meridian, as determined by day-time observations of the North Star, we mapped the north line of Massachusetts from Boundary Pine to northwest corner on a much larger scale than Borden's map. This line, barring slight irregularities, resembled very closely the curve of a parallel of latitude, whereas the straight line passed 900 ft. north of Belding, instead of 300 ft. south of it as Barbour had stated. This led to a discussion in which he contended that a straight *course* and a straight *line* were not synonymous terms, but what bearing could that straight line question have on the fences and other marks supposed to indicate the Massachusetts and Vermont state line?

There we left it, Professor Barbour dying June 4, 1901. In his death the Vermont University suffered an irreparable loss. He was a useful and much respected citizen, a perfect gentleman

in his deportment, and the idol of the students in the class room. Whether Professor Barbour was the originator of the straight-line boundary scheme, or whether that was the invention of the Vermont commissioners, I never knew, but these commissioners gave the surveyors instructions not to notice town corners or to make any ground measurements; notwithstanding this injunction, our party cut out the line from Connecticut River to Jilson Hill and measured it with steel tape and plumb rods in the same manner as we had measured the line from the said river to the ocean, and on our own responsibility we procured and set town corner monuments on all the Massachusetts town corners as far as Jilson, and later the Massachusetts commissioners ordered all the Massachusetts town corners on the Barbour line monumented.

While the state of Massachusetts had been expending from \$10 000 to \$20 000 a year during the past 10 years for the purpose of locating town corners by triangulation, these Vermont Boundary Line Commissioners, three lawyers, totally ignored all the town corners on their state line, and forbade their surveyors marking any of them. These Vermont commissioners, after their straight-line scheme had changed the entire 41.5 miles of the state line and left all the town corners with nothing to indicate their location on the new line, coolly informed us that they were making things certain which were before uncertain. They seem to have got their dictum wrong end up, and have actually made things very uncertain which were before certain. The simple fact that there has been no dispute over the location of the state line for more than a century and a half settles this question most effectually. After an expenditure of some \$54 000 by the three states, about 100 miles of it are in a much worse condition to-day than before the recent commissions were authorized.

DISCUSSION.

Mr. Frank W. Hodgdon (*by letter*). — Much of the paper is devoted to describing the manner in which the line should have been marked in the opinion of the author rather than as it was actually run out and marked by direction of the commissioners appointed by the three states for doing the work, whose work was later approved by the legislatures of the three states.

In the early part of the paper he says that the New Hampshire boundary line had never been established by the joint action of the two states, while later in the paper he says, two states are not competent to establish the boundary line.

He also says that there is a neutral zone lying between two lines over which neither state can exercise jurisdiction, but as both states have agreed to the same line it is difficult to see how there can be any neutral zone between them.

Having been one of the Massachusetts members of the commission which made the final report establishing this line, and having, so far as I was able, obtained all the information which could be secured in relation to the methods of running out and marking the line, a short statement of the way in which the line has been established, marked and re-marked may be interesting.

After much mutual misunderstanding in relation to the northern boundary of Massachusetts, the King and Council in 1740 fixed the line as 3 miles north of and parallel with the northerly bank of the Merrimack River from the sea to a point 3 miles north of Pawtucket Falls, now Lowell. From this point the line was to run due west to his Majesty's other possessions. This line was run out and marked by blazing trees under the direction of the governor of the provinces of Massachusetts and New Hampshire.

No further marking of the line was done by state authority until 1825 to 1827, when the line was re-examined by commissioners from both states, who reported that they had found the line as marked by the surveyors in 1741, and along this line stone bounds were set by a surveyor employed by Massachusetts, New Hampshire taking no part in re-marking the line, but her commissioners reporting jointly with the Massachusetts commissioners that they had found the line as marked in 1741.

No further investigation of the line by the authorities of both states was made until the recent commission was appointed in 1885, although in the meantime, when the survey of the state was made by Mr. Simeon Borden, certain bounds were set by him to mark a few points on the line. It would not appear that he had any authority to set bounds which would represent anything else than his individual opinion as to where the line was. During this period, also, various other bounds had been set along the line and many stone walls built supposedly on the state line, but these were placed and constructed without authority from either state and were principally for the purpose of marking property lines and the intersection of town boundary lines with the state line.

When the recent commission made its survey of the line it identified to its satisfaction practically all the angle points in the line between the sea and Lowell, as marked by the surveyors in 1741 and 1827; westerly along the straight portion of the line

it found many of the bounds set in 1827 and decided that in its opinion the nearest approach which they could identify to the line as originally run out was a line connecting the bounds marking the various town corners along the state line, most of these having been set by the Massachusetts surveyor in 1827. The variation from the straight line can be readily accounted for by the comparatively rough character of the instruments used in running out the line originally.

The border between Massachusetts and Vermont had never been examined by any state authority, so far as I can learn, since it was originally run out in 1741, and there were practically no marks made at that time which could be identified by the recent commission. For this reason a different and somewhat arbitrary scheme had to be and was adopted. From all the facts obtainable the commissioners were satisfied that they had re-marked the line substantially as it was originally run out. The author of the paper, who was surveyor for Massachusetts, did not agree with the decision of the joint commissioners, his argument being largely that the line should follow the property lines established by individuals rather than the marks fixed by state authority. The principle of law is well known to all surveyors that in a description of land a bound on the ground should be accepted as marking the line rather than a course and distance given in a deed, but the bound must have been placed by some competent authority, and in this case the only bounds placed by competent authority were the trees marked by the surveyors in 1741 and the bounds set by the Massachusetts surveyor in 1827. Property owners and local authorities, while intending to conform to the true line, frequently took inadequate measures for determining the line. A case which came to my knowledge recently was where the local authority of an adjoining state extended the town water pipes across the line to supply a number of houses on the Massachusetts side of the line, thinking and believing, so far as I was able to learn, that the buildings in question were on the other side of the line, — the buildings and land on which they stood being taxed by the town in the adjoining state. In this case no attempt had been made to accurately run out the line, but local opinion that the line was beyond the houses in question was relied upon. The question of necessity of action by Congress does not arise in this case as no attempt has been made to establish a new line, but simply on the best information obtainable to re-run and re-mark the line as originally fixed by decree of the King.

The same is true of the western boundary of Massachusetts.

the portion of which from Alandar Mountain to Vermont was re-run and re-marked as nearly as could be done on the line originally laid out in 1787, many of the original monuments being found and the line passing within 2 or 3 in. of all permanent marks found and through many of the stone piles, generally within a few feet, never more than 4 ft. from their centers. As along the northern boundary, many walls and bounds had been set by owners and town officers which were found at considerable distances from the line as run out. As no re-marking had been done by state authority since the original marking in 1787, these bounds and property fences were not considered in the final location, enough of the original marks having been found to identify the location of the original line throughout its whole length.

In regard to the northwest corner, no evidence was obtained that the small bound found there, said to have been set by Simeon Borden, marked any point in either the survey of 1741 of the northern boundary or the survey of 1787 of the western boundary; and as it did not agree with the other marks practically identified on the western boundary the intersection of the two lines as determined from the investigation of the various commissioners was fixed as the corner of the state rather than the point marked by the Borden monument.

All the lines as re-examined and re-marked in recent years have been adopted by the legislatures of the respective states as marking the true line, excepting the boundary between Massachusetts and New York. This has been accepted by Massachusetts and it is expected that it will shortly be accepted also and adopted by New York, when the facts become fully known.

In the 27th Report of the Massachusetts Harbor and Land Commissioners for the year 1905 there is, on pages 46–62, a summary of the history of the monumenting of the state boundaries, near the end of which it is stated as to whether or not an act of Congress ratifying the action of states in delineating a common boundary line is essential to the validity of the jurisdiction so determined, that

" it would seem that an agreement or compact between two states, which, in establishing a boundary line, set over or interchanged inconsiderable areas for the purpose of straightening or more clearly indicating the same, the effect of which bore upon property rights only, and had no tendency to change the power or political relationship already existing between the states themselves or in their relationship to the United States, would not be repugnant to the Constitution or require the confirmation of Congress."

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1906, for publication in a subsequent number of the JOURNAL.]

FIRES AND THEIR PREVENTION IN FACTORIES.

By F. B. Sanborn, Member of the Boston Society of Civil Engineers.

[Read before the Society, June 20, 1906.]

Ten years ago the magnitude of fire losses in this country was about 140 million dollars each year. Five years ago the annual losses amounted to about 160 million, and for the year 1905, 175 million. These have been average years, and it will be noted that the losses have increased from 140 million to 175 million during the period of ten years. Inasmuch as the country has been increasing in wealth and prosperity during this period, the increase in losses is little more than proportional to the whole growth of the country. But the discouraging feature is that the aggregate amounts for the succeeding years have not been materially reduced, even lessened by one half.

The present averages, 150 to 175 million annually, have been greatly exceeded one year during the past ten, namely in 1904. In that year occurred the great Baltimore fire, and the annual loss rose to 230 million. That fire occurred in February; and December 30 preceding came another serious fire, namely the Iroquois Theater holocaust; and in the June following occurred a third fire of equal horror, namely, that of the excursion steamer *General Slocum* in New York Harbor. These three fires, Baltimore, Iroquois, *General Slocum*, considered in conjunction with the recent devastation at San Francisco, form four important object lessons of which I wish first to speak briefly.

The Baltimore fire burned through the business part of the city, an area about 0.25 mile wide and 1 mile long. The fire lasted 30 hr. and consumed about 70 million dollars worth of property. Contrast this fire with that of the

Iroquois Theater: Here, instead of 30 hr. as at Baltimore, the fire lasted 30 min. Instead of 70 millions loss, an insignificant amount. Instead of 1 person killed, 588 persons were killed and 250 injured. Baltimore taught the lesson anew that sweeping conflagrations are possible even in modern cities; and Iroquois showed the awful destruction of human lives that is imminent in many theaters and auditoriums.

A different but equally impressive lesson was shown by the *General Slocum* fire that occurred about this same time, namely, on June 15, 1904. This excursion steamer was carrying a German Lutheran Sunday-school; about 1 200 passengers. Of this number about 960 were lost by the fire and by drowning — not on the open seas, but within hailing distance of the shores of greater New York; in fact, near the very spot where, 24 years previously, another steamer met a similar fate. Yet the burning of the *Slocum* is said to have been the worst harbor disaster that has been recorded in the history of American catastrophes.

The story of San Francisco is fresh in our minds. Beginning the morning of April 18, 1906, earthquake and fire wrecked some 3 sq. miles of the business section of the city. The total monetary loss attributable to the fire is, at this time, difficult to estimate and will ever be only approximate on account of the indeterminate destruction that was wrought by the earthquake. Present estimates place the loss that should be charged to the fire as 200 million dollars. Undoubtedly this has been the greatest conflagation in our history. With water mains broken, little resistance could be offered by the fire-fighting facilities. City steamers were used intermittently and buildings razed to the ground by dynamite, but the conflagation once well under way swept on until vacant lots, wide streets or opposing forces of wind could stop it. Some reporters have stated that around the city the atmospheric conditions were calm and normal, but within a roaring furnace created a gale of wind and cross currents that swept inward and upward. A noteworthy feature of this San Francisco catastrophe has been the remarkable fortitude and splendid courage shown by thousands of homeless citizens. Now that the worst is over these valiant people have opportunity to show our American communities a second object lesson, namely, a city of modern construction and with improved fire protection; better than our average American city; better than our new Baltimore.

When we stop to consider three great fires and the sum total of annual losses the question arises how to prevent such sweeping conflagations, how to reduce the total annual loss by one half. A method that was started 70 years ago, and which has been successful in factories, is one that I desire to speak of in the following paper.

Beginning with a few cotton mills in Rhode Island the

system has extended until now it includes, in one form or another, most of the leading manufacturing plants of the middle west and the southern and eastern states. The largest of these factory associations is the Factory Mutual system. This system now comprises about 2 500 factories. The total insurable value represented is about 1 billion, 2 hundred million dollars ($1 200 000 000). The system extends through Canada, the New England states, New York, Pennsylvania, Ohio, Indiana, Illinois, Wisconsin and nearly all of the Southern States.

The engineering and inspection departments of these associated companies have been brought to high standards of organization and serviceableness by the foresight and notable perseverance of our fellow member, John R. Freeman.

Four essential elements are made pre-eminent in forming an estimate of these factories: Good general order and neatness, good construction (combining with that, construction to overcome exposures), safe occupancy and reliable fire protection. These four conditions, order, construction, occupancy and protection, together constitute the quality of the fire risk as a whole. There are, however, bound to be variable conditions among different factories. In construction there are the light joisted buildings of the Middle States, and older mills of New England, the brick and steel girder floors of some silk and jute mills, the heavy plank and timber floors and roofs of modern mills now common in North and South, and a few of the new style concrete plain and reënforced.

In occupancy the conditions vary from the crowded miscellaneous manufactures of a single building in which are made upholstery, jewelry, plush, paper boxes, dress goods and men's wear, to the building with product plain and simple of unfinished iron castings.

The protection, furthermore, as will be easily understood, is the most variable of all. From the mill, located miles away from any fire department, which boasts that fire pails "skillfully applied" are ample to save that "particular mill" from any fire that can start, to the modern equipped mill with chemical extinguishers, automatic sprinklers, hydrants, hose, elevated tank, city water, special pumps and private reservoir. This disparity in order, construction, occupancy and protection of different factories can only be kept to a minimum by some system common to all, and effectively sustained. This is done in the aforesaid factories through the medium of insurance companies with their systems of frequent inspections, supple-

mented by cheaper insurance, prevention against business interruptions and losses that always result from any serious fire.

Any wise manager quickly discerns the advantages of lower rates of insurance and uninterrupted business, and he will adopt reasonable requirements for safeguards when convinced of the value of them, but some means must be employed to present those requirements, whereby one factory will be placed on a par with another. This requires a corp of engineers and inspectors who are employed in investigating the many phases of fire prevention and means of reducing fire hazards to a minimum. In the Associated Factory Mutual Companies there are 14 regular inspectors constantly going through factories; and so extensive has this system become that for any one inspector to complete the whole circuit of factories and return to his starting point requires $4\frac{2}{3}$ years.

I was employed in this work for 7 years and recently during summer months, and I venture to say a word about the inspection work, leaving the subjects of costs and savings in insurance that accrue by adopting improved construction and fire protection to another speaker.

The primary duty of an inspector is to compare one mill with another; to point out defects; to suggest improvements; to examine all conditions that affect the probabilities of a serious fire. Is there likely to be a fire? Where? Of what magnitude? What are the most practicable means of avoiding a fire?

At each mill he visits he is required to fill out a report. This report will indicate his judgment of the general order and neatness, the condition of oily waste, fire doors, fire hose, mill fire brigade, electric equipment, automatic sprinklers, yard hydrants, fire pumps, public water supplies, building construction, occupancy and general fire protection. Then at the end he gives his estimate of the risk as a whole.

In order to fill out these inspection sheets accurately and with good judgment, the inspector must go through the property from top to bottom and see all items that in any way affect the good or poor qualities of the property as a fire risk.

He will usually begin at the top of a group of buildings, slowly walk through all rooms in company with some representative of the mill and examine as he goes along the general order; the occupancy in regard to machinery, stock in process, the amount and in a general way its value, the system of fire protection, which will include fire pails, small hand hose, automatic sprinklers and perhaps special devices like chemical extinguishers,

steam jets, rubber blankets and so on, noting on his sheet those items that go to make up his estimate of the top story of the factory. He proceeds downward through each story, looking at fire doors, fire shutters, sprinkler valves, construction of floors, thickness of walls, just as he has done in the room above. In the basement he will often find more to examine with special care, because here may be stored machinery, yarn in cases, cloth in bales, sometimes cotton or wool; the rooms are not so well lighted and there is apt to be less open space for operation

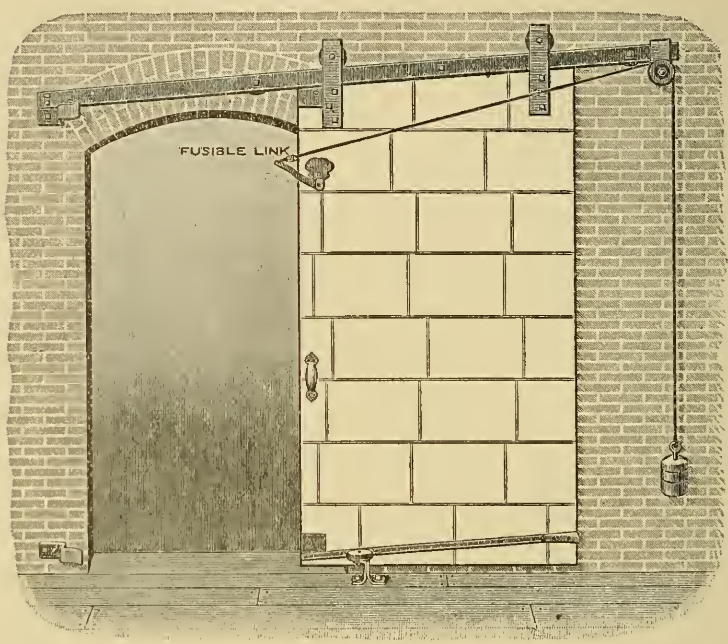

Fig. 1. A Standard Self-Closing Fire Door on an Inclined Track and with a Fusible Link.

during a fire. Here are, too, in the older mills usually, some of the main shut-off valves on 4- and 6-in. sprinkler pipes, which must be examined carefully in order to report positively whether they are open or shut; because, as will be evident, if one of these main valves becomes closed, as I have many times found to be the case, the whole protective system of sprinklers and hose throughout the building is cut off from its water supply.

Having finished his examination of the main group of buildings, he passes through the other buildings in the yard, which comprise storehouses, sheds and often boiler houses,

repair shops and certain classes of rooms with dangerous occupancy, as, for example, those that contain oils, rag pickers, gas processes, waste bins. In regard to this variety of occupancy he must judge of the special dangers of each. If any compartment of the storehouses contain over $100 000 worth in value, that fact should be noted. The protection afforded these disconnected buildings should vary directly as the value and increased hazard; that is, large values, $100 000 for example, should have automatic sprinklers in nearly every case with yard pipes ample for delivering good supply to the sprinklers and affording 6 to 8 standard fire streams from hydrants. Or if the building and contents are likely to burn quickly, they must be well isolated and it must be possible to smother the fire by adequate protection.

In order to judge properly of the efficiency of the protection, the inspector makes an actual test once every year. This test comprises trial of the fire pumps at their full capacity with delivery of water through lines of hose attached to the hydrants. The engineer or mechanic at the mill runs the pumps as hard as he would attempt to run them during an actual fire. The inspector notes the water pressure at the pump, the number of revolutions, length of stroke, smoothness of action, horse-power of boilers or water wheels that furnish the power and then in the yard at the hydrants the lengths of hose lines, sizes of nozzles and pressure that is being maintained at the hydrants. From these data he can compute the gallons of water delivered per minutes and make up his estimate of the general condition of the pump service. He then tests the city water supply and by proper gage readings can also estimate the number of fire streams that would be available from this source, because his final report must include a reliable estimate of the total number of fire streams that he considers to be available from pumps, public water and city steam fire engines combined.

The usual method of measuring the quantity of discharge from pumps or city water pipes is by observing the pressure, while water is being delivered through fire streams, by a gage screwed into a hole tapped in a hydrant or attached to a nozzle plug as shown in illustration. The pressure thus taken at an average hydrant serves for the 4 or 6 streams that are usually in operation. Then by referring to Freeman's Fire Stream Tables the discharge is determined. This method of using the hydrant pressure by which to determine the discharge permits of probable errors of 5 to 10 per cent. due to uncertain conditions

of the inside surface of hose. But by the device shown in Fig. 2 the pressure can be read directly at the nozzle. This device can be applied to a stream without shutting off the flow and without fastening any attachments to the nozzle; the weight of the gage and a slight pressure from the hand are sufficient to keep it in place at the tip of the nozzle, while the pressure is being read.

The essential parts of this nozzle piezometer are: A bent tube, acting as a Pitot tube, that transmits the pressure; a divider having knife edges that cut the water; and a shield that prevents the water from spattering seriously. I experimented with my first form of this device last summer while inspecting factories and testing pumps and water supplies, and during the past few months further experiments have been made by one of our Tufts engineering students (Mr. N. E. Hadley) with a view to determining the accuracy and practicability of the device.

As to accuracy for different positions in which the piezometer may accidentally be placed we have found that the pressure remains constant for all positions in the streams until the very edge is reached, so that with this size of tube practically only the full pressure can be read.

An advantage in taking the pressure at the nozzle instead of taking it at the hydrant lies in the fact that friction losses in long lines of hose are thereby eliminated.

Last summer at a test in a mill yard at Fitchburg, Mass., I found that with 400 ft. of linen hose and 1.25-in. nozzle a hydrant pressure of 146 lb. afforded only 43 lb. on a nozzle piezometer. This loss in pressure from 146 lb. to 43 is at first thought surprising, and although fire stream tables indicate this amount of loss it cannot be fully appreciated until actually observed, as is done when the pressure is taken at the nozzle instead of at the hydrant. Also it is nozzle pressure that really tells the force and effectiveness of the stream.

Besides its use for testing purposes this device may be found to have practical value in fire departments for taking the pressure that fire streams have at time of fire. Because of the lack of such record after a fire there are often many futile arguments as to the pressure that streams really possessed during a fire. In order to indicate the number of gallons flowing through given sizes of nozzles I have designed a gage dial that has inside graduations for pressures in lbs. per sq. in. and outside graduations for reading directly the discharge in gal. per min. for a given nozzle.

FIG. 2. GAGE DIAL AND NOZZLE.

FIG. 3. STREAM, AND MAN STANDING ON HOSE.

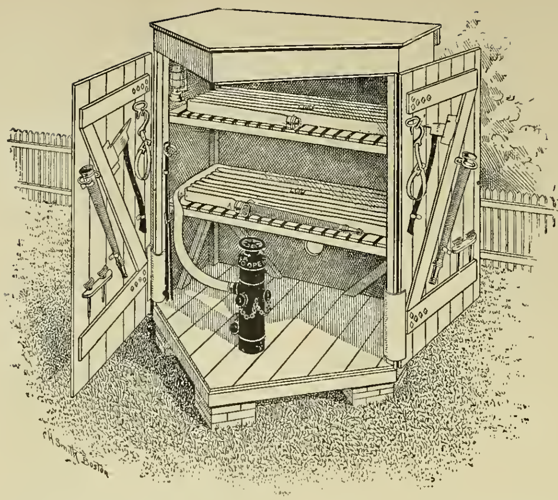

Fig. 4. A Hose and Hydrant House with Full Equipment: 200 Ft. of Cotton Rubber-Lined Hose, 2 Bars, 4 Spanners, 3 Playpipes, 2 Ladder Straps, 1 Nozzle Holder and 1 Heavy Mill Lantern.

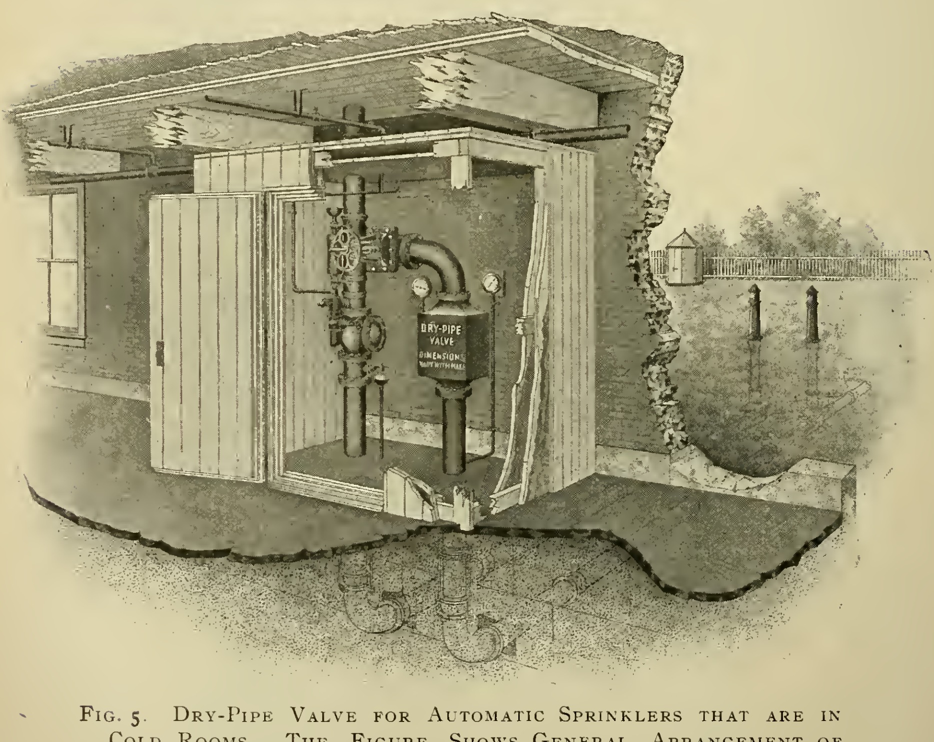

Fig. 5. Dry-Pipe Valve for Automatic Sprinklers that are in Cold Rooms. The Figure Shows General Arrangement of Valve, which is Placed in a Long By-Pass with Controlling Valves and Indicator Posts Located 50 to 100 Ft. away from Building so as to be Accessible during a Fire.

TEST OF THE ACCURACY OF THE NOZZLE PIEZOMETER AS DESIGNED BY F. B. SANBORN, CIVIL ENGINEER, FOR MEASURING THE PRESSURE AND DISCHARGE OF WATER FLOWING FROM FIRE NOZZLES.

Date and Time.	Size of Nozzle.	Pressure at Base of Play Pipe. Lb. Sq. In.	Pressure Corrected.	Discharge of Nozzle. Gal. per Min.	Correction for Velocity Past Gage.	Static Pressure above Nozzle.	Pressure by Nozzle Piezometer. Lb. per Sq. In.	Pressure by Nozzle Piezometer Corrected.	Error of Nozzle Piezometer.	Per Cent. Error in Pressure.	Per Cent. Error in Gal. Flowing.
May 1, 1906											
3.50 P.M.	$1\frac{1}{8}$	14	16	150.4	0.6	16.6	14.5	16	— 0.6	3.3	1.9
3.55 ,,	$1\frac{1}{8}$	47	49	263.2	2.0	51.0	47.5	49	— 2.0	3.9	2.1
3.58 ,,	$1\frac{1}{8}$	50	52	271.2	2.1	54.1	50.5	52	— 2.1	3.9	2.1
4.29 ,,	$1\frac{1}{8}$	34.5	36.5	226.8	1.5	38.0	35.0	36.5	— 1.5	3.9	2.1
4.30 ,,	$1\frac{1}{8}$	58	60	291	2.4	62.4	59.5	61	— 1.4	2.3	1.2
4.32 ,,	$1\frac{1}{8}$	64	66	305.2	2.7	68.7	65	66.5	— 2.2	3.2	1.6
4.33 ,,	$1\frac{1}{8}$	62	64	300.6	2.6	66.6	63.5	65	— 1.6	2.4	1.3
4.35 ,,	$1\frac{1}{8}$	65	67	307.4	2.7	69.7	66.5	68	— 1.7	2.5	1.2

As a result of field and laboratory tests Mr. Hadley says that he finds the per cent. of error in gallons flowing under pressure from 20 to 100 pounds would safely be said not to exceed 3 per cent.

These graduations are indistinctly shown in Fig. 2. The face of the dial gives the quantities for 10, 20, 30 lb. up to 100, and the back of the gage has a table for 5, 15, 25 lb. up to 95. Between these values interpolations can be made to the nearest pound.

In the foregoing I have referred to tests of factory pumps and public water supplies, and I now wish to emphasize the great importance of completely separating one of these supplies from the other. The public supply is sometimes given by direct pumping, but usually it consists of a gravity supply from reservoir or tank. When a factory has not the benefit of a public water supply it must erect its own tank or reservoir with capacity of 50 to 100 thousand gal.

The secondary supply in factories is usually fire pumps of large capacity connected with storage reservoirs that will last from 1.5 to 2 hr. This pump service must in no way rely upon city water to assist it; even the priming supply, which is required when the pump has to lift its water, must be independent; and the steam that drives the pump must, if necessary, be produced without the use of city water in the boilers. The importance of making the second supply entirely independent of the primary supply must never be disregarded.

At San Francisco, Baltimore and other large cities where conflagrations have quickly wiped out the whole business section and destroyed millions of dollars worth of property, the urgent need has been for a source of protection, strong and effective, that could be used independently of city water. At Baltimore numerous instances occurred where successful resistance was offered to the path of the conflagration by these independent sources of supply, and an excellent example of this sort was afforded by the fire of February 9, 1902, at Paterson, N. J. This fire started about midnight in a repair shop adjoining some wooden car sheds. A gale was blowing from the northwest — about 40 miles an hour — with the temperature 20 degrees above zero, unusually cold for that locality. Thus conditions enabled the fire to gain headway rapidly. Its sweep is shown on the map. It burned about a quarter of a mile, jumped three squares, then went on again for another quarter of a mile.

As the fire approached the mills, preparations were made to meet it with their utmost defense. Their pumps were ready; steam was up; storage reservoirs were full; men were on duty and others came to help them; lines of hose were run out 300 to 500 ft., thus to check the advance of the fire. As no city steamers or other apparatus were in this vicinity everything depended on

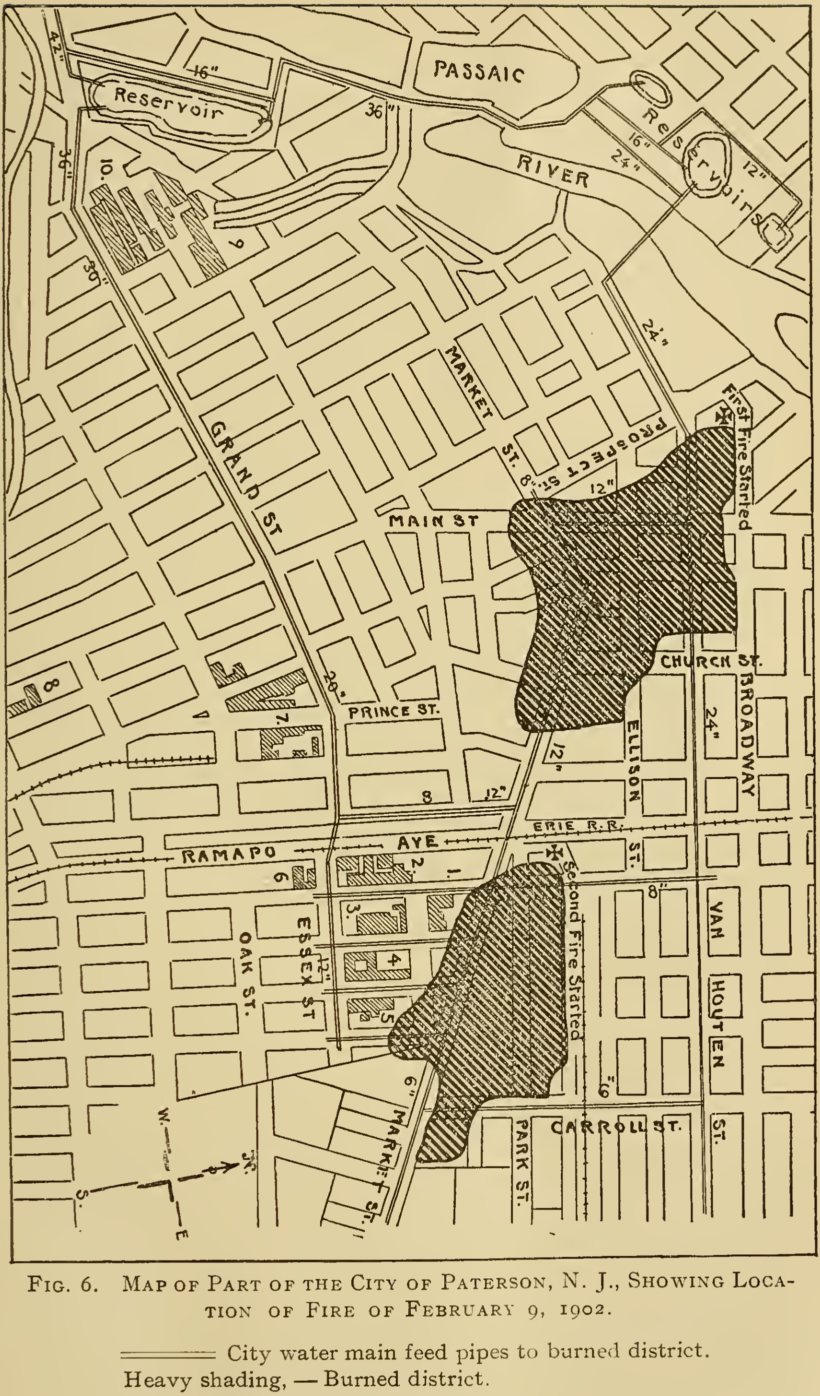

FIG. 6. MAP OF PART OF THE CITY OF PATERSON, N. J., SHOWING LOCATION OF FIRE OF FEBRUARY 9, 1902.

═══════ City water main feed pipes to burned district.
Heavy shading, — Burned district.
Light shading, — Mutual risks.

the mill apparatus. The success of the men's efforts is shown by the limits of the black area, which extends to within 75 ft. of one mill, 70 ft. of another and 50 ft. of a third.

I have mentioned four conditions — order, construction (coupling with that exposure), occupancy and protection — that go to make up an inspector's estimate of a factory as a fire risk. All of these four conditions deserve full consideration, but I am

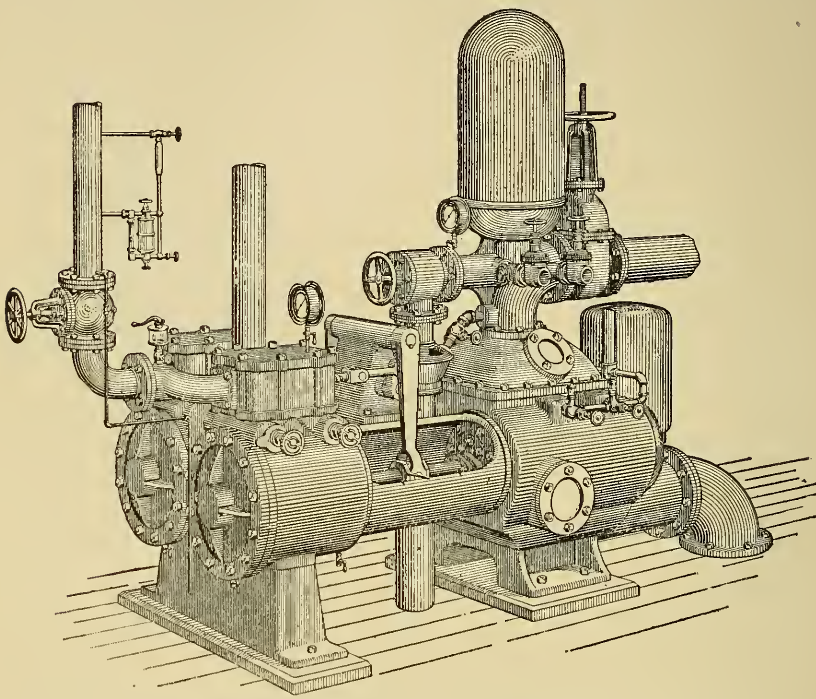

FIG. 7. AN UNDERWRITER FIRE-PUMP WITH STANDARD FITTINGS.

limiting my paper principally to two of the four, — protection and construction. Of these two I can only speak briefly and in a general way. I have already referred to some of the elements of good protection. As to construction in factories there exist two principal classes, both of which classes usually have walls of brick, stone or concrete, but are distinguished according to the construction of floors and roofs; one as joisted, the other as plank and timber.

As one observes slow-burning construction or improved fire protection becoming common in many factories the question naturally arises, Why are not means of better construction and protection with a second source of supply provided more exten-

sively in our cities, especially for business blocks, theaters and public buildings? The answer is that such changes are wrought by a very slow process. There are the owners and proprietors to be convinced; the engineers and especially the architects who often persist in having primarily "architectural effects" at the expense of good engineering; the public official and even the voter. But I earnestly believe that these great lessons — 200 million dollars consumed in this country annually: in a single conflagration, as at Baltimore, 70 million, and three times that amount at San Francisco; in terms of human lives, 586 lost in half an hour at Chicago, 960 on the *General Slocum* — will lead to the introduction of safeguards and methods of fire prevention similar to those which so many of our leading manufacturing industries have shown to be both possible and practicable.

DISCUSSION.

Mr. S. G. Walker.* The speaker proposes, in a few words, and with pertinent facts and figures, to convey an idea of the scope of the Factory Mutual Companies in the insurance field, and their instrumentality in the development of fire protection on specific lines.

There are several groups of mutual companies who confine their operations to the insurance of manufacturing properties, but the present consideration will be confined to the senior group of New England, who, from their great advantage as to age, volume of business and financial strength, are in a position to be most discriminating in the class of risks they assume, and consequently to produce insurance at the lowest possible cost, and who are directly responsible in great degree for the development of the modern protective system.

Some seventy years ago a group of the representative manufacturers of Rhode Island who, from superiority of construction and other considerations affecting their risks, deemed themselves entitled to concessions in the matter of rates, but having been denied such consideration, joined forces to assume their own insurance, and, in 1835, a charter was granted them under the name of the Manufacturers Mutual Fire Insurance Company of Rhode Island.

The original plan of operation was to charge a rate of premium which would produce funds thought to be sufficient for

* Insurance engineer, with Manufacturers Mutual Fire Insurance Company of Providence, R. I.

the comfortable operation of the company, which was about two thirds of the then existing rate of the stock companies, and, after deducting fire losses and operating expenses, return the balance, if any, to the assured in the form of a so-termed dividend; or, in case of a deficit, an assessment was to be levied, sufficient to cover the shortage. It having proven necessary to so assess the members on several occasions, the arrangement appeared cumbersome and, in 1844, the present plan was adopted and the original rate of premium changed to roughly that charged by the stock companies, to the end that the officers were possessed of sufficient funds for prompt payment of losses and comfortable operation, and although it is a provision of law embodied in the policy that a member may be assessed to the extent of five times his premium, there has never been an assessment since that time. This fact is the more remarkable when it is considered that in the early days there was practically no protection which would be worthy of consideration as such to-day, and it was largely a matter of good fortune, and in some cases good management, as to whether the mills stood or burned.

The event, however, proved the feasibility of the scheme of insurance and the wisdom of its originators, for the system grew rapidly, new members were added and other companies formed in neighboring communities, and from this nucleus has sprung a system of 14 allied companies, carrying the insurance of over 2 000 distinct manufacturing plants and now writing 1.25 billions of dollars annually, on properties covering a territory from Halifax, Nova Scotia, to the Gulf of Mexico, and as far west as the Mississippi.

By far the greater proportion of this tremendous business is at present on risks in New England and the Middle States, and so advantageous has the system proven that probably 90 per cent. of the factories in New England, which are of such class as to be eligible for the insurance, are carried in these companies, while among the remainder there are many instances where personal considerations outweigh pecuniary advantage and cause the insurance to be placed through the stock companies' agents.

The ages of the companies are as follows:

Manufacturers	71 years
Rhode Island	58 ,,
Boston Manufacturers	56 ,,
Firemens	52 ,,
State	51 ,,
Worcester	51 years

Arkwright	46 years
Blackstone	38 ,,
Fall River	36 ,,
Mechanics	35 ,,
Merchants	33 ,,
Enterprise	32 ,,
American	29 ,,
Paper Mill	16 ,,

and of them, 9, including the 2 oldest, are in Providence and the remainder in Massachusetts.

The administration of the affairs of the companies is vested in the respective boards of directors, who are elected by the members, and are individually interested to a large extent in the insurance, and consequently faithful in their attendance at meetings and strict in the careful disposition of funds at their disposal.

As has been stated, the initial premium is far in excess of any sum which it is expected will be expended, and the balance, after covering expenses for operation and the payment of losses, is returned to the assured as a dividend.

On last year's business the gross premiums amounted to $9 252 000, or an average rate of 75 cents per $100, the individual rates varying from that figure according to character of respective risks.

The cost of operation was divided as follows:

Salaries and office expenses	$241 140
Inspection Department, including plans, appraisals, adjustments and inspections, regular and special,	155 540
Taxes	137 190
Total	$533 870

or about 5.75 per cent. of premiums.

The economy of operation is illustrated in no better manner than by comparing this ratio with that of expense of operation of the stock companies, which is about 40 per cent. of the annual premiums, the average premium on all classes being, if anything, larger with them.

The fire losses last year amounted to $529 530, again about 5.75 per cent. of the premiums, and the loss by accidental discharge of water from the sprinkler system, insurance against which damage is furnished by these companies without extra premium, was $38 400, or about 0.4 per cent. of the premiums, making a total expenditure of $1 101 800, or 12 per cent. of the premiums.

The moneys as they are received are invested, together with a surplus of $1 941 000, which has been accumulated through accretion in value of securities held and the wise administration of directors in the past, and this interest account, which last year amounted to $399 720, is applied towards the expenditures, leaving a net disbursement of $702 080, which is 7.6 per cent. of the gross premiums and only 6.3 per cent. of the total assets, and the companies were enabled last year to pay dividends ranging between 90 per cent. and 95 per cent. in the various instances, making the average net cost of insurance about 5.5 cents per $100.

For a term of 5 years past the dividends have ranged between 88.8 and 93.2 per cent., making the cost of insurance about 6.75 cents, and for a term of 10 years the dividends have ranged from 88.7 to 91.7 per cent., with an average net cost of insurance of about 7.5 cents per $100.

In analyzing this extremely low cost we find the economy of operation to be due to a great extent to the fact that all business is conducted from the office direct, and thus the expensive item of agents' commissions is avoided, and, at the same time, the offices are kept in intimate acquaintance with the characteristics of the risks assumed. Then there are no stockholders demanding profits, the only beneficiaries being the manufacturers themselves; furthermore, the frictionless manner of conducting the offices, coupled with the spirit of absolute fair-mindedness with which adjustments are approached, is responsible for the fact that lawsuits over settlements of loss are unknown, and expensive legal expenditures are avoided; but above all these important factors is the highly discriminating policy which demands that a risk, before being admitted, shall conform to certain standards as regards construction, occupancy, protection, exposure and management.

The standard of construction is the typical American mill construction, with brick walls and plank and timber floors and roofs wherein the combustible material is so disposed, in large masses, with smooth surfaces and a minimum of angles, as to retard combustion, and it is well named "slow-burning construction," for, in the experience of the mutual companies, there is no instance of a factory floor of this type without openings having burned completely through during the progress of a fire. A risk deviating from this standard beyond certain limits will not be acceptable for mutual insurance.

In matters of occupancy, elimination of extra hazardous

operations, isolation of the most dangerous processes, susceptibility of stock to damage by water or smoke and the possibilities of salvage when damaged, are all features which affect the eligibility of risks.

In the consideration of protection, the automatic sprinkler is unquestionably the most vital feature, as it has proved to be the most effective known appliance for the control of internal fires, for with a modern equipment in good order, there will be a sprinkler where needed and when wanted; it will work in smoke and flame and where the fireman is defied, and with a minimum of water damage in proportion to efficiency; it has in its action no dependence upon that which may be said to be only reliable for its fallibility, — human agency; it presupposes the axiom that "fire will start," and proceeds to confine fires to the locality of their incipiency, and it is hardly to be imagined that disastrous proportions will be reached in the face of such an equipment.

The mutual companies, through their officers and corps of engineers, have unquestionably been the most potent factor in the development, first of the perforated pipe systems, to which water was admitted when needed by opening valves, and which was designed to furnish inside protection, necessity for which had been demonstrated; then open-head systems, a decided advance in arrangement and distribution, though still involving extensive water damage, and finally the automatic sprinkler system in its successive stages from the first experimental equipment installed in Fall River in 1872, through its gradual adoption over the most hazardous departments in the cotton factories to the present standard of 100 per cent. sprinklered, based on the unfortunate faculty of fires for starting in unexpected places from equally unsuspected causes.

First to recognize the importance of such protection, the manufacturers, as represented by the mutual companies, have reaped rich rewards through reduction in insurance cost, although other companies refused for some years to concede the value of sprinklers by a reduction, their claim being that the liability of water damage without fire more than offset the advantage in protection, the fallacy of which stand is indicated by the fact that this liability is assumed by the mutuals without extra premium.

Even as recently as within 10 years sprinklers were not deemed essential over certain classes of occupancy, and it was an exceptional instance when a storehouse, other than for cotton or other fiber, was equipped; but from the mutual standpoint it is

preferable to buy sprinklers than to buy factories even piecemeal, and the wisdom of the present standard may be illustrated by a comparison of the dividends of 91 per cent. for the past 5 years with 87.4 per cent. for the preceding 5 years period and 70 per cent. for a period of 10 years previous to that.

Before the introduction of sprinklers the dividends fluctuated widely, in fortunate years even reaching the figures of to-day, but the average over terms of years indicates plainly not only the steadying of dividends, which is, of course, desirable, but the increase in average which improved protection has been responsible for; and since their general adoption it has been demonstrated that a heavy loss in a thoroughly protected factory may, as a probability, be considered negligible.

The cost of a sprinkler equipment is, of course, dependent upon varying conditions as to construction, the labor market and the competitive feature, and to such a degree as to render its expression in figures of doubtful guidance, but in general the cost will be between 3 and 5 cents per sq. ft. of floor area for the inside work alone, and a total of between 6 and 10 cents per sq. ft. of floor area including the provision of adequate supplies; thus the expense of a system is not great when it is considered that it is the best fireproofing device known, as it fireproofs building and contents as well.

Wholly aside from its value as a protective equipment and the consequent insurance against the interruption of production, with attendant business losses not covered by the insurance policy, the installation of a system is commonly one of the best of investments viewed from a business standpoint, through the saving effected in cost of insurance, as it is not unusual to show a saving of 90 per cent. of such cost, and the return on the amount invested will frequently net 20 per cent. and not uncommonly 50 per cent. annually.

As the mutual companies do not assume the insurance on unsprinklered risks and their net cost is usually materially under that of the stock companies, the saving would not be as great as above noted between a sprinklered and unsprinklered risk if the insurance is to be continued as before, but there should be a saving of 60 to 70 per cent., especially when conditions are such as to render the risk suitable for mutual insurance when protected and consequently subject to competition.

The feature of exposure is critical from the standpoint of the mutual companies, and their refusal to accept risks where subject to the hazard of congestion has resulted in their im-

munity from loss in any of the large conflagrations which have occurred within the period of their history. Whenever exposures are sufficient to demand serious consideration without affecting the acceptance of a risk, powerful fire pumps become an essential feature of the protection, and their value has, perhaps, never been better demonstrated than at the Paterson fire, where the pumps at the mutual risks not only saved them from destruction but, being in the path of the conflagration, were largely instrumental in preventing its further spread.

The value of careful management in the prevention of fires is beyond question, as more fires start from carelessness or preventable causes than from all others combined, and, as prevention is preferable to extinction however prompt, the general order and neatness of a plant is one of the most vital of all considerations in its standing as a fire risk, and the high standard prevailing in mutual risks as a whole in this respect is due to the efficiency of its inspection department, a corps consisting of picked men chosen for qualifications which peculiarly adapt them for efficient work, and each reporting on the risks he visits from the point of view of his previous training, but all in accordance with a scheme devised to emphasize the vital features of each case.

There are at present 14 men employed on this force, and 3 inspections of each risk are made during the year; so with the present number it takes a man somewhat over 4 years to complete the rounds, and meanwhile the officers are kept in intimate touch with conditions at the risks. By no means the least valuable feature of this system is the profit to the manufacturer from these periodical visits by men of the broadest knowledge in all matters concerning fires, their prevention and extinction, and many a heavy loss has been prevented by the timely discovery by an inspector of defects in detail or general condition of the apparatus, one such discovery often warranting the expenditure of thousands of dollars in its attainment.

This matter of the necessity for ever readiness of fire apparatus recalls to mind the case of a certain rural community, where a volunteer fire brigade with an antiquated hand pumping engine was maintained, and on the occurrence of a fire it appeared that the pump, from a long period of disuse, had developed stubbornness, and, when it was finally limbered up, the hose proved defective, all of which operated to the uninterrupted consumption of the structure on fire. This occurrence occasioned the calling of a special town meeting to take action, and one of the town fathers, to settle the matter and prevent a

recurrence of such calamities, moved that a fire committee be appointed, whose duty it should be to examine the condition of the apparatus in future 10 days before each fire, and this is in principle the result obtained by the maintenance of the mutuals' inspection department.

The secret of success of the mutual system is the disposition of the companies in every possible way to save money to the manufacturer, giving him his insurance at the lowest possible eventual cost, and to this end the policy is written on the broadest and most liberal basis possible.

An indication of the possibilities of the system in future is seen in the record for the past year of the 6 companies of which Mr. John R. Freeman is president, namely, the Manufacturers, Rhode Island, Mechanics, State, Enterprise and American, and which had a total loss on $410 000 000 insurance of only a little over $145 000, while the interest on invested assets amounted to nearly $147 000; in other words, the interest income more than covering the losses, the cost to the assured simply represented cost of operation of offices and their proportion of inspection department expenses.

Proportionate reduction in future cost hardly seems probable, as there can be no reasonable advance in the requirements for protection, although perfection in detail at the individual risk will lessen the occasional losses of unusual severity due to a combination of circumstances or of minor defects of preventable nature, which separately would be harmless.

The limit has not as yet been reached in economy of operation, for within certain limits an increase in volume of business is not attended with proportionate increase in expense of operation.

In view of the history of the companies, with a growth of 8 per cent. last year and practically doubling the volume of business in 10 years, it seems probable that the mutual system is destined to eventually cover the entire field of manufacturing activity in the United States, for the alert manufacturer will purchase his insurance, as he does other commodities, in the cheapest market.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 1, 1906, for publication in a subsequent number of the JOURNAL.]

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AZIMUTH, LATITUDE AND TIME FROM POLARIS AND A SOUTHERN STAR, WITH SURVEYOR'S TRANSIT.

By George O. James.

[Read before the Engineers' Club of St. Louis, October 18, 1905.]

Section 1.

Of the two ordinary methods of obtaining an approximate azimuth from Polaris and a southern star, one requires a measurement of the horizontal angle between the two stars, together with the chronometer times of bisection, while in the other this horizontal angle is made 180 degrees by setting on Polaris and then transiting the telescope through the wyes and observing the instant of passage of the southern star across the vertical thread. Comstock* gives a good account of the first method, and Seares† of the second. In this paper I have developed a form of reduction for the second method, which is at once rapid and convenient and gives a very good approximation of the azimuth of the Pole Star at the instant of bisection, the error not amounting to one tenth of a minute of arc.

The method of observing is as follows: Polaris is bisected by the vertical thread and the time noted. Then, *without changing the instrument in azimuth*, the instant of passage of a southern star across the vertical thread is noted. From the *interval* between the two bisections the azimuth of Polaris is computed, and a knowledge of the chronometer correction is, therefore, not necessary.

A watch set *roughly* to local sidereal time is necessary for finding the southern star, and the interval may be measured

* "Field Astronomy for Engineers," p. 90.

† Bulletin No. 5, Laws Observatory, University of Missouri.

on this same timepiece. A sufficiently close value of the local sidereal time is given by

$$\theta' = T_c - \Delta\lambda + Q \qquad (1)$$

Where

$T_c \equiv$ Watch time.
$\Delta\lambda \equiv$ Longitude of observer west of standard meridian.
$Q \equiv$ Sidereal time of Washington Mean Noon.

$\Delta\lambda$, if not otherwise known, may be taken with sufficient accuracy from a map, and Q is taken from the *American Ephemeris and Nautical Almanac* (published each year by the Bureau of Equipment, Navy Department, Washington, D. C., price $1.00), page 400.

The southern star will transit nearly at the time

$$\theta' = \alpha, \qquad (2)$$

the difference being due

First, to the error in θ'.

Second, to the telescope not being exactly in the meridian.

The first of these will depend on the error in $\Delta\lambda$, and will probably not exceed 5 min. with a good map, while the second will never be greater than 10 min. in the United States and will generally be much less.

If Polaris is west of the meridian, the southern star will transit early and should be watched for a little ahead of time.

In order that the southern star may pass across the field of the telescope, this must be set at zenith distance,

$$z = \varphi - \delta, \qquad (3)$$

where

$\varphi \equiv$ Observer's Latitude.
$\delta \equiv$ Declination of Southern Star.

The latitude need be known to the nearest minute only, and if this rough value is not known it may be obtained with sufficient accuracy by observing the altitude of Polaris and then using the table at the end of the *Ephemeris*.

The observed altitude may be used directly in this preliminary determination of a rough value of the latitude, as the refraction correction will affect the southern star to much the same extent that it does Polaris and the differential correction may be neglected.

If θ' is correct to within 10 min. of time, the local sidereal time read directly from the watch will give the latitude to within 2 minutes of arc, and much greater errors will still throw the southern star in the field of the telescope, which is all that

is desired. This rough computation of latitude may be made in a few minutes on the spot.

Suitable southern stars may be always chosen from the list "Mean Places of Standard Stars," published each year in the *Ephemeris*.

The azimuth of Polaris at the instant of bisection is computed as follows:

The hour angle of a star is

$$\tau = \theta - a,$$

where

$\theta \equiv$ Local Sidereal Time.
$a \equiv$ Apparent Right Ascension of Star.

Hence, for Polaris, $\tau_0 = \theta_0 - a_0$, and for the southern star, $\tau = \theta - a$.

Therefore,

$$\begin{aligned} \tau - \tau_0 &= (a - a_0) - (\theta - \theta_0) \\ &= (a - a_0) - (T_c - T_{0c}) - \Delta''' (T_c - T_{0c}), \end{aligned}$$

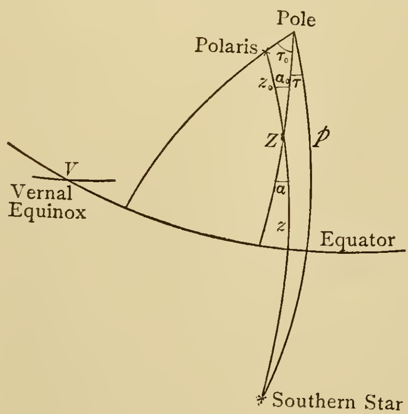
where

$T_{0c} \equiv$ Watch time of bisecting Polaris.
$T_c \equiv$ Watch time of bisecting star.
$\Delta''' \equiv$ Correction required to reduce mean interval $T_c - T_{0c}$ to corresponding sidereal interval $\theta - \theta_0$.

This correction may be taken from Table III at the end of the *Ephemeris*, with $(T_c - T_{0c})$ as argument.

Setting $Z \equiv$ Observer's Zenith,
$\zeta \equiv$ Observer's Colatitude,
$p \equiv$ North Polar Distance of Star,
$z \equiv$ Zenith Distance of Star,
$a \equiv$ Azimuth of Star,

and letting subscripts ($_0$) refer to Polaris, we have from the figure



$$\frac{\sin\ \tau_0}{\sin\ z_0} = \frac{\sin\ a_0}{\sin\ p_0}$$

$$\frac{\sin\ \tau}{\sin\ z} = \frac{\sin\ a}{\sin\ p}$$

Whence, $$\sin\tau = \sin a\,\frac{\sin\ z}{\sin\ p}.$$

Now, $a = -a_0$, and $p = 90 - \delta$.

Whence, $$\sin\tau = -\sin p_0\,\frac{\sin\ \tau_0}{\sin\ z_0}\,\sin z \sec\delta.$$

Again, $z = \varphi - \delta$ very nearly, and $z_0 = 90^\circ - (\varphi - \varepsilon_0)$, where ε_0 is the small correction tabulated on the last page of the *Ephemeris* with τ_0 as argument.

Therefore,

$$\sin\tau = -\sin p_0 \sin(\varphi - \delta)\sec\delta\sec(\varphi - \varepsilon_0)\sin\tau_0;$$

or,

$$\tau = -p_0\sin(\varphi - \delta)\sec\delta\sec(\varphi - \varepsilon_0)\sin\tau_0, \qquad (6)$$

since both τ and p_0 are small.

Since τ is small, an approximate value of τ_0 is

$$\tau_0' = (a - a_0) - (T_c - T_{oc}) - \varDelta'''(T_c - T_{oc}). \qquad (7)$$

A value of τ, generally correct to within 1 sec., is then given by

$$\tau' = -p_0\sin(\varphi - \delta)\sec\delta\sec(\varphi - \varepsilon_0')\sin\tau_0', \qquad (8)$$

and $$\tau_0 = \tau_0' + \tau'. \qquad (9)$$

Whence, $$a_0 = p_0\sec(\varphi - \varepsilon_0)\sin\tau_0. \qquad (10)$$

Collecting the necessary formulæ:

$$\left\{\begin{array}{lll} \tau_0' & = (a - a_0) - (T_c - T_{oc}) - \varDelta'''(T_c - T_{oc}). & [1] \\ \tau' & = -p_0\sin(\varphi - \delta)\sec\delta\sec(\varphi - \varepsilon_0')\sin\tau_0'. & [2] \\ \tau_0 & = \tau_0' + \tau'. & [3] \\ a_0 & = p_0\sec(\varphi - \varepsilon_0)\sin\tau_0. & [4] \end{array}\right.$$

The a and δ used in the computation should be taken from "Apparent Places of Standard Stars" in the *Ephemeris*.

The following example illustrates the computation:

Station: W. U. *Date:* May 7, 1905.

	T_c		
Polaris	10^h	15^m	17^s
a Virginis	10^h	20^m	$33^s.5$

Computation.

$$
\begin{aligned}
a &= 13^h\ 20^m\ 13^s \\
a_0 &= 1\ \ 24\ \ 17 \\
a - a_0 &= 11\ \ 55\ \ 56 \\
-(T_c - T_{oc}) &= \ -5\ \ 16.5 \\
-\varDelta'''\,(T_c - T_{oc}) &= \ -0.9 \\
\hline
\tau_0' &= 11^h\ 50^m\ 39^s \\
&= 177^\circ\ 39'.8
\end{aligned}
$$

$$
\begin{aligned}
p_0 &= \ 72'.2 \\
\phi &= 38^\circ\ 39' \\
\delta &= -10\ \ 40 \\
\varepsilon'_0 &= 1\ \ 12 \\
\varphi - \delta &= 49\ \ 19 \\
\varphi - \varepsilon'_0 &= 37\ \ 27
\end{aligned}
\qquad
\begin{aligned}
\log(-p_0) &= 1.8585n \\
\log\sin(\varphi - \delta) &= 9.8799 \\
\log\sec\delta &= .0076 \\
\log\sec(\varphi - \varepsilon'_0) &= .1002 \\
\log\sin\tau'_0 &= 8.6104 \\
\hline
\log\tau' &= .4566n
\end{aligned}
$$

$$
\begin{aligned}
\tau' &= -2'.9 \\
\tau_0 &= 177^\circ 36'.9
\end{aligned}
$$

$$
\begin{aligned}
\log p_0 &= 1.8585 \\
\log\sec(\varphi - \varepsilon_0) &= .1002 \\
\log\sin\tau_0 &= 8.6192 \\
\hline
\log a_0 &= .5779 \\
a_0 &= 3'.8
\end{aligned}
$$

If the azimuth of a mark is desired, several readings on mark and Polaris should be taken, and combined with an observation on Polaris and a southern star as follows:

Let $M \equiv$ Mean of circle readings on Mark.
$M_0 \equiv$ Mean of circle readings on Polaris.
$N \equiv$ Circle reading on North.
$T_{om} \equiv$ Mean of watch times of bisecting Polaris.
$\tau_{om} \equiv$ Hour angle of Polaris at T_{om}.
$a_{om} \equiv$ Azimuth of Polaris at T_{om}.
$T_{oc} \equiv$ Time of transit of Polaris.
$T_c \equiv$ Time of transit of Southern Star.
$\tau_0 \equiv$ Hour angle of Polaris at transit.

Then

$$
\left\{
\begin{aligned}
\tau_{om} &= \tau_0 + (T_{om} - T_{oc}) + \varDelta'''\,(T_{om} - T_{oc}). && [1] \\
a_{om} &= p_0 \sec(\varphi - \varepsilon_0)\sin\tau_{om}. && [2] \\
N &= a_{om} + M_0. && [3]
\end{aligned}
\right.
$$

In the following example four settings on Polaris were made, two with circle east and two west, and at the fourth bisection the transit of the time star δ Sculptoris was observed.

$$
\begin{aligned}
M_o &= 179^\circ\ 2'.4 \\
T_{om} &= 23^h\ 25^m\ 14^s.5 \\
T_{oc} &= 23\ \ 35\ \ 43 \\
T_c &= 23\ \ 38\ \ \ 3.5 \\
a &= 23\ \ 43\ \ 58 \\
a_o &= \ \ 1\ \ 25\ \ 57 \\
a - a_o &= 22\ \ 18\ \ \ \ 1 \\
-(T_c - T_{oc}) &= \quad -2\ \ 20.5 \\
-\Delta'''(T_c - T_{oc}) &= \qquad\quad -.4 \\
\hline
\tau_o' &= 22^h\ 15^m\ 40^s \\
&= -26^\circ\ 5' \\
\hline
\log(-p_o) &= 1.8573n \\
\log \sin(\varphi - \delta) &= 9.9659 \\
\log \sec \delta &= \ .0567 \\
\log \sec(\varphi - \varepsilon_o') &= \ .1160 \\
\log \sin \tau_o' &= 9.6431n \\
\hline
\tau' &= \qquad 43'.6 \\
\tau_o &= -25^\circ\ 21'.4 \\
T_{om} - T_{oc} &= -2\ \ \ 37.1 \\
\Delta'''(T_{om} - T_{oc}) &= \qquad\quad 0.4 \\
\tau_{om} &= -27^\circ\ 59' \\
\log p_o &= 1.8573 \\
\log \sec(\varphi - \varepsilon_o) &= \ .1160 \\
\log \sin \tau_{om} &= 9.6714n \\
\hline
\log a_{om} &= 1.6447n \\
a_{om} &= \qquad -44'.1 \\
M_o &= 179^\circ\ \ 2'.4 \\
N &= 178^\circ\ \ 18'.3
\end{aligned}
$$

This is exactly the value obtained by more accurate and extended computation. The value of N combined with that of M gives the azimuth of the mark.

Section 2.

An approximate determination of the observer's latitude may be made from an observation on Polaris and a southern star combined with a series of measurements of the altitude of Polaris. The mean of these corrected for refraction gives the altitude of Polaris at the mean of the observed times. Comstock's formula for refraction is

$$R = [2.6898] \frac{\cot h'_m}{456 + F}$$

where $R \equiv$ Refraction in minutes of arc.
$[2.6898] \equiv$ Logarithm of numerical factor.
$h'_m \equiv$ Mean of observed altitudes.
$F \equiv$ Temperature in degrees Fahrenheit.

The hour angle τ_{om}, of Polaris at the mean instant, T_{om} having been computed as above, the latitude is given by

$$\varphi = h_{om} - p_o \cos \tau_{om} + [\bar{4}.1627]\, p_o^2 \sin^2 \tau_{om} \tan h_{om}$$

where all terms in the right-hand member except the first are in minutes of arc.

The following example will illustrate the method:

The mean of six altitudes of Polaris — three circle east and three west — gave

$$h'_{om} = 37^\circ\ 45'.45$$
$$T_{om} = 8^h\ 47^m\ 9^s.5,$$

while the times of transit of Polaris and the southern star θ Virginis were

$$T_{oc} = 9^h\ 54^m\ 39^s.5$$
$$T_c = 10\quad 5\quad 15$$

From the *Ephemeris* for the date May 7, 1905:

$$\alpha = 13^h\ 5^m\ 3^s.5 \qquad \delta = -5^\circ\ 2'$$
$$\alpha_o = 1\ 24\ 16.5 \qquad \delta_o = 88\ 47.85$$
$$p_o = 72.15$$

$$\alpha - \alpha_o = 11^h\ 40^m\ 47^s$$
$$-(T_c - T_{oc}) = -10\ 35.5$$
$$-\Delta'''(T_c - T_{oc}) = -1.7$$

$$\tau_o' = 11^h\ 30^m\ 10^s$$
$$= 173^\circ\ 10'$$

$$\varphi = 38^\circ\ 50' \text{ (rough)} \qquad \log(-p_o) = 1.8584n$$
$$\varepsilon_o' = 1\ 12 \qquad \log\sin(\varphi - \delta) = 9.8407$$
$$\varphi - \delta = 43\ 52 \qquad \log\sec\delta = .0017$$
$$\log\sec(\varphi - \varepsilon_o') = .1013$$
$$\varphi - \varepsilon_o' = 37\ 38 \qquad \log\sin\tau_o' = 9.0755$$

$$\log\tau' = .8776n$$

$$\tau' = -7'.544 = -1^m\ 53^s$$
$$\tau_o = 11^h\ 28^m\ 17^s.$$

$$T_{om} - T_{oc} = -1^h\ 7^m\ 30^s$$
$$\Delta'''\ (T_{om} - T_{oc}) = \quad -11$$
$$\tau_{om} = 10^h\ 20^m\ 36^s$$
$$= 155^\circ\ 9'$$
$$h'_{om} = 37^\circ\ 45'.45$$
$$R = \quad 1.225$$
$$\text{1st term} = h_{om} = 37^\circ\ 44'.22$$

$$\log p_0 = 1.8582 \qquad \qquad \bar{4}.1627$$
$$\log \cos \tau_{om} = 9.9578\ n \qquad 2 \log p_0 = 3.7164$$
$$\text{sum} = 1.8160\ n \qquad 2 \log \sin \tau_{om} = 9.2470$$
$$\text{2d term} = -65'.47 \qquad \log \tan h_{om} = 9.8887$$
$$\text{sum} = \bar{1}.0148$$
$$\text{3d term} = 0'.104$$

$$\varphi = 37^\circ\ 44'.22 + 65'.47 + 0'.104$$
$$= 38^\circ\ 49'.8$$

Section 3.

If the observer's longitude is known to within 2 min. of time, a good approximation of the chronometer correction on local mean time may be obtained from a single setting on Polaris and a southern star with very little additional computation.

The necessary equations are:

$$\tau_0' = a - a_0 - (T_c - T_{oc}) - \Delta'''(T_c - T_{oc}), \quad [1]$$
$$\tau' = -p_0'' \sin(\varphi - \delta) \sec \delta \sec (\varphi - \varepsilon_0') \sin \tau_0', \quad [2]$$
$$\tau_0 = \tau_0' + \tau', \quad [3]$$
$$\tau = -p_0'' \sin(\varphi - \delta) \sec \delta\ \mathit{sec}\ (\varphi - \varepsilon_0) \sin \tau_0, \quad [4]$$
$$\theta = \tau + a, \quad [5]$$
$$T = (\theta - \Theta) - \Delta''(\theta - \Theta) - \Delta''\lambda, \quad [6]$$
$$\Delta T_c = T - T_c, \quad [7]$$

where $\Theta \equiv$ Sidereal time of Greenwich Mean Noon.

$\Delta'' \equiv$ Correction required to reduce a sidereal interval to the corresponding mean interval.

$\lambda \equiv$ Observer's longitude west of Greenwich.

The correction Δ'' may be taken from Table II at the end of the *Ephemeris* with sidereal interval as argument.

Station: W. U. *Date:* May 7, 1905.

Observer.	Beals.			Traber.		
Southern Star.	α Virginis.			π Hydrae.		
T_{oc}	10^h	15^m	17^s	10^h	53^m	45^s
T_c	10	20	33.5	11	2	11.5

Reduction.

$\varphi = 38^\circ\ 39'$ $\lambda = 6^h\ 1^m$

$p_0 = 4329''$	α Virginis.			π Hydrae.		
α	13^h	20^m	$13^s.0$	14^h	0^m	$59^s.8$
α_0	1	24	17	1	24	17
$\alpha—\alpha_0$	11	55	56	12	36	43
$—(T_c—T_{oc})$		—5	16.5		—8	26.5
$—\Delta'''(T_c—T_{oc})$			—.9			—1.5
τ_0'	11^h	50^m	39^s	12^h	28^m	15^s
	177°	$39'.8$		187°	$3'.8$	
φ	38^h	39^m		38^h	39^m	
δ	—10	40.1		—26	13.6	
ϵ_0'	1	12.1		1	11.7	
$\varphi—\delta$	49	19.1		64	52.6	
$\varphi—\epsilon_0'$	37	26.9		37	27.3	
log $(—p_0'')$	3.63639n			3.63639n		
sin $(\varphi—\delta)$	9.87986			9.95684		
sec δ	.00757			.04718		
sec $(\varphi—\epsilon_0')$	.10023			.10027		
sin τ_0'	8.61035			9.08979n		
log τ'	2.23440n			2.83047		
τ'	$—171''.6=$	$—2'.9=$	$—11^s.4$	$676''.8=$	$11'.3=$	$45^s.1$
τ_0	11^h	50^m	$27^s.6$	12^h	29^m	$00^s.1$
	177°	$36'.9$		187°	$15'.1$	
ϵ_0	1	12.1		1	11.6	
$\varphi—\epsilon_0$	37	26.9		37	27.4	
log $(—p_0'')$	3.63639n			3.63639n		
log sin $(\varphi—\delta)$	9.87986			9.95684		
log sec δ	.00757			.04718		
log sec $(\varphi—\epsilon_0)$	.10023			.10028		
log sin τ_0	8.61924			9.10206n		
log τ	2.24329n			2.84275		
τ	$—175''.1=$		$—11^s.7$	$696''.2=$		$46^s.4$
α	13^h	20^m	13^s	14^h	0^m	$59^s.8$
θ	13	20	1.3	14	1	46.2
Θ	2	58	37.94	2	58	37.94
$\theta—\Theta$	10^h	21^m	$23^s.36$	11^h	3^m	$8^s.26$
$—\Delta''(\theta—\Theta)$		—1	41.80		—1	48.64
$—\Delta''\lambda$			—59.14			—59.14
T	10^h	18^m	42.42^s	11^h	0^m	$20^s.48$
T_c	10	20	33.5	11	2	11.5
ΔT_c		—1	51.1		—1	51.0

The collimation error in the transit may be eliminated by combining two observations on two southern stars of nearly equal declinations, one observed with circle east and the other with circle west.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 15, 1906, for publication in a subsequent number of the JOURNAL.]

THE RECONSTRUCTION OF THE OLIVE STREET TRACK.

By Richard McCulloch, Member of the Engineers' Club of St. Louis.

[Read before the Club, September 19, 1906.]

The first street railway track laid in the city of St. Louis was that laid on Olive Street from Fourth Street to Fourteenth Street. The original rail was a flat strap rail, and the road was opened for traffic as a horse-car line on the Fourth of July, 1859. The initial trip was the occasion of great public rejoicing, as it was considered that a great step in the city's progress had been made. As the city grew, Olive Street developed into an important retail business street, and the Olive Street line became the artery uniting the business district with the most important residence district of the city.

In 1887 the Olive Street line was converted into a cable line, a double cable track being built from Fourth Street to Boyle Avenue, a distance of 3.5 miles. In this construction a girder rail, 4½ in. in height, weighing 63 lb. per yard, was laid on cast-iron yokes weighing 300 lb. each, set in concrete 4 ft. apart. These yokes were 48 in. in depth and inclosed a conduit for the

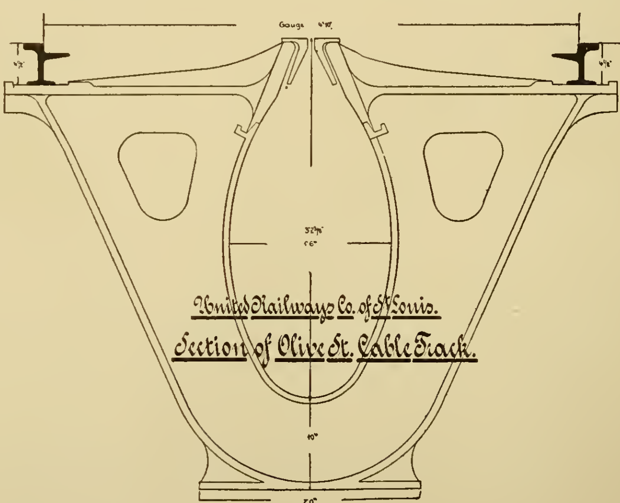


Fig. 1.

cable 38 in. in depth. A cross-section of this construction is shown in Fig. 1. This cable road was one of the first built east of San Francisco. All of the St. Louis cable roads adopted the 38-in. conduit. In cable roads afterwards built in New York City the conduit depth was reduced to 24 in., making a much stronger roadbed, and greatly reducing the cost of construction.

The original rail having worn out, in 1898 the rail of the cable road was renewed. In the original construction the rail had been bolted directly to the yokes by means of hook bolts without the use of chairs, and it was, therefore, impossible to increase the height of the rail on the yokes. In the 1898 reconstruction an extra heavy section of 4½-in. rail weighing 67 lb. per yard was used. In 1901 the road was converted into an electric road, electric cars being operated over the cable roadbed without change.

This rail, however, was entirely too light for service under heavy electric cars. In 1903, the year before the World's Fair, about one half of the track was relaid, the portions selected for relaying being the downhill parts of the track where the speed of the cars was greater. In the 1903 reconstruction it was not considered advisable to take the cars off the street during the reconstruction, and the very novel method of laying the track with a 9-in. rail for the outside rail and a 6⅝-in. rail for the inside rail was adopted. The 9-in. rail was laid 7 in. outside of the

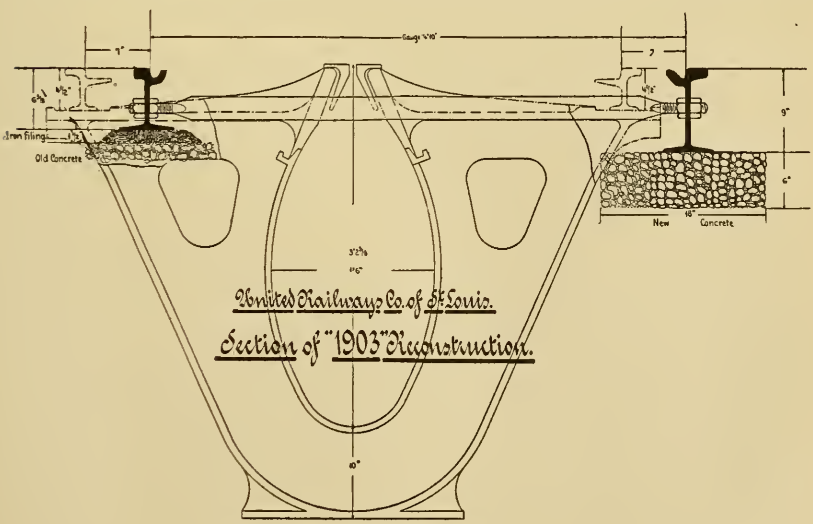


FIG. 2.

gage line of the track on a concrete stringer 18 in. wide and 6 in. deep. The 6⅝-in. rail was laid on the old concrete of the cable road and tamped to surface with a mixture of iron borings and salt about 1½ in. deep. The concrete under the 9-in. rail was given about 5 days to set. The bed of iron borings under the 6⅝-in. rail was given only a few hours to set, as the rail was laid at night and cars run over it the next day. The two rails were tied together by steel tie rods spaced 6 ft. apart. Fig. 2 shows this construction. The reasons for this unusual construction were to enable the track to be relaid without interfering with car service on the street, and to avoid the expense of excavating the concrete roadbed of the cable road. The results obtained, however, were not at all satisfactory. The shallow concrete stringer under the 9-in. rail broke in a number of places and left this rail without support. The iron borings under the 6⅝-in. rail did not set to form a hard mass, and this rail, being left loose, deflected up and down as cars went over it, working the paving loose and emitting a horrible grinding and chattering noise which gave rise to constant complaint. The two rails were not sufficiently tied together, and frequent wide gage was the result.

In the spring of 1906, when it was necessary to relay the old cable track on account of the rail being worn out, that portion of the track reconstructed in 1903 was in such bad condition that it was considered best to relay both of the tracks and put the street into first-class shape.

In order to understand the need for speed in the construction, it should be stated that the Olive Street line is the one having the heaviest traffic in the United Railways system. During the middle of the day the cars are 1.5 minutes apart, and night and morning during the hours of heaviest travel, the headway between cars is reduced to 50 seconds. Olive Street throughout its entire length is a narrow street, only 36 ft. wide between curbs, and lined with retail stores. As a concrete construction for the track was decided upon, it was necessary to remove the cars from each track during its construction. The street being entirely too narrow for a third temporary track, it was necessary to route the cars over another parallel line. Hence, any delay in the progress of the construction would mean annoyance to the residents and shopkeepers along the street, inconvenience to the regular patrons of the line and loss of traffic to the railroad.

After a number of plans had been considered, it was decided to perform the work in two sections, building both tracks between

Lane
Ave.
Theresa
Ave.
Rankin Ave.
Papin
Atlantic St.
Scott
Bernard
Rankin
Theresa
Clark
Clark Ave.
Walnut St.
Ave.
Str.
Ave.
Str.
Lindell Ave.
Olive St.
Theresa
Ave.
St. Alphonsus
Easton
Cass
Ave.

TES ON ACC

Fig. 3. United Railways Company of St. Louis. Map Showing Change in Routes on Account of Reconstruction of Olive St. Tracks.
Reconstructed Tracks indicated ——— Temporary Track used during Reconstruction indicated .—.—. Routes of Olive Street Cars during Reconstruction indicated - - - -

Fourteenth Street and Boyle Avenue (29 118 ft. of track equal to 5.51 miles) early in the spring, and that portion between Sixth Street and Fourteenth Street (3 670 ft. of track equal to 0.69 miles) during the middle of the summer. The work between Sixth Street and Fourteenth Street was postponed until the summer at the request of the merchants on lower Olive Street, who did not like to see their spring trade interfered with.

It was decided to use the single track on Olive Street not under construction for west-bound cars, sending east-bound Wellston cars down Washington Avenue and across Fourteenth Street to Olive Street, and the east-bound McPherson and Maryland cars over Boyle Avenue to Laclede Avenue, down Laclede Avenue and across Thirteenth Street to Olive Street. Fig. 3 shows this routing. In order to make these changes in routing, a temporary track was laid in Boyle Avenue from Maryland Avenue to Laclede Avenue, a distance of about 1 500 ft. This temporary track was laid with 75 lb. T-rail spiked to wooden ties, the ties being placed on top of the brick pavement of the street. In passing, it is interesting to note that when this temporary track was removed after cars had been running over it for six weeks, absolutely no damage whatever had been done to the brick pavement.

For the new track there was adopted a girder Trilby rail, 9 in. high, laid on cypress ties spaced 2 ft. between centers. Brace tie plates and Goldie claw tie plates were used on alternate

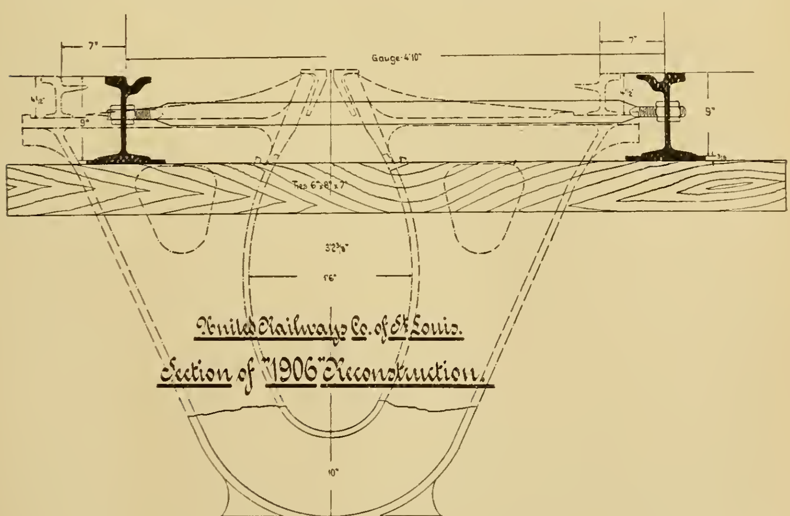


FIG. 4.

ties. Tie rods, 2 in. by $\frac{3}{8}$ in. in section, were spaced 6 ft. apart. Six inches of Portland cement concrete was placed beneath the ties, and the concrete was carried up high enough on the rail to support the style of paving adopted, making a thickness of 14 in. of concrete in the case of granite paving and 18 in. for asphalt paving. In either case the wooden tie was entirely embedded in the concrete. This construction is shown in Fig. 4. For the first portion of the reconstruction the work was divided into three sections: Section No. 1, Fourteenth Street to Jefferson Avenue; section No. 2, Jefferson Avenue to Grand Avenue; section No. 3, Grand Avenue to Boyle Avenue. Each of these sections is about a mile of double track. Three separate foremen with independent gangs were put in charge, each foreman in charge of a section. Work was carried on day and night.

Excavation.

In order to build the track, it was necessary to make an excavation 21 in. in depth in a concrete which had been setting for 18 years, and which experience in whatever excavations had been made had shown to be extremely hard. If it had been necessary to pick out six miles of this concrete by hand the cost would have been excessive, and, disregarding the cost, the time involved and the number of men required would have been prohibitory of that method.

Drilling and Blasting.

The method adopted for excavating the concrete was by blasting with small charges of dynamite, the object being to make these charges strong enough to shatter the concrete so that it could be taken out in large pieces, but not heavy enough to do other damage. Holes were drilled 7 to 8 in. deep in the concrete, four holes between each pair of yokes. The hole was so located that the bottom of the hole was a little below the center of gravity of the section of concrete to be removed. The location of the holes is shown in Fig. 5. For drilling the holes there were used No. 2 Little Jap drills made by the Ingersoll Rand Company, operated by compressed air at 90 lb. pressure. This tool drills a 1.25-in. hole. A dry hole is drilled, the exhaust air from the hollow drill steel blowing the dust from the hole and keeping it clean. Common labor was used to run the drills and very little mechanical trouble was experienced. Three cars were fitted up, one for each gang, each car being equipped with

a motor-driven air compressor, water for cooling the compressors being obtained from the fire plugs along the route. The air compressors were taken temporarily from those in use in the repair shops, no special machines being bought for the purpose.

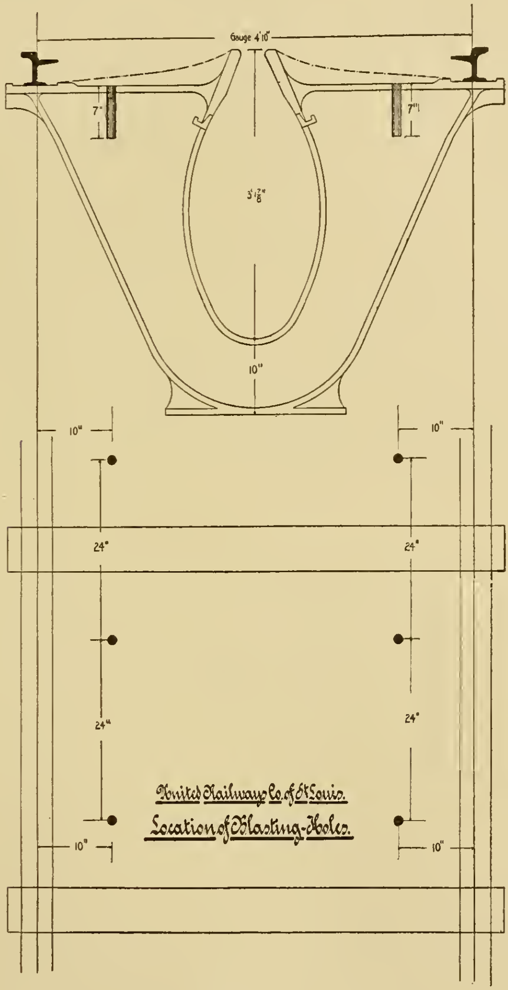


Fig. 5.

Current for operating the air compressor motors was taken from the trolley wire over the tracks. The car was moved along as the holes were drilled, air being conveyed from the car to the drills through a flexible hose. Two drills were operated nor-

mally from each car. One of the air compressors was exceptionally large and at times operated four drills. The total number of holes drilled in the reconstruction of the track was 31 000. The total feet of hole drilled was 20 700 feet. The following figures give the average performance of the best one of the drilling outfits, which operated from two to three drills:

Depth of hole	8 in.
Number of holes per hour per drill	30
Feet of hole drilled per hour per drill	20.3
Labor cost per foot of hole drilled	$0.027
Labor cost of drilling per cu. yd. blasted	$0.085
Drilling cost per lineal foot of track	$0.017
Drilling cost per mile of track	$89.76

In these figures there is no charge for electric power or for depreciation of machinery.

For blasting, a 0.1 lb. charge of 40 per cent. dynamite was used in each hole. A fulminating cap was used to explode the charge, and twelve holes were shot at one time by an electric firing machine. The dynamite was furnished from the factory in 0.1 lb. packages, and all the preparation necessary on the work was to insert the fulminating cap in the dynamite, tamp the charge into the hole and connect the wires to the firing machine. In order to prevent any damage being done by flying rocks at the time of the explosion, each blasting gang was supplied with a cover car, which was merely a flat car with a heavy bottom and side boards. When a charge was to be fired, this car was run over the twelve holes and the side boards let down, so that the charge was entirely covered. This work was remarkably free from accidents. There were no personal accident claims whatever, and the total amount paid out for property damages for the whole six miles of construction was $685. Most of this was for glass broken by the shock of explosion. There was no glass broken by flying particles. The men doing this work, few of whom had ever done blasting before, soon became very expeditious in handling the dynamite, and the work advanced rapidly. The report made by the firing of the twelve holes was no greater than that made by the giant fire-crackers so common in the streets on the Fourth of July.

For the drilling and blasting the old rail had been left in place to carry the air compressor car and the cover car. After the blasting, this rail was removed and the concrete excavated to the required depth. In most cases the cable yokes had been

FIG. 6. PNEUMATIC DRILLS AND COMPRESSOR CAR.

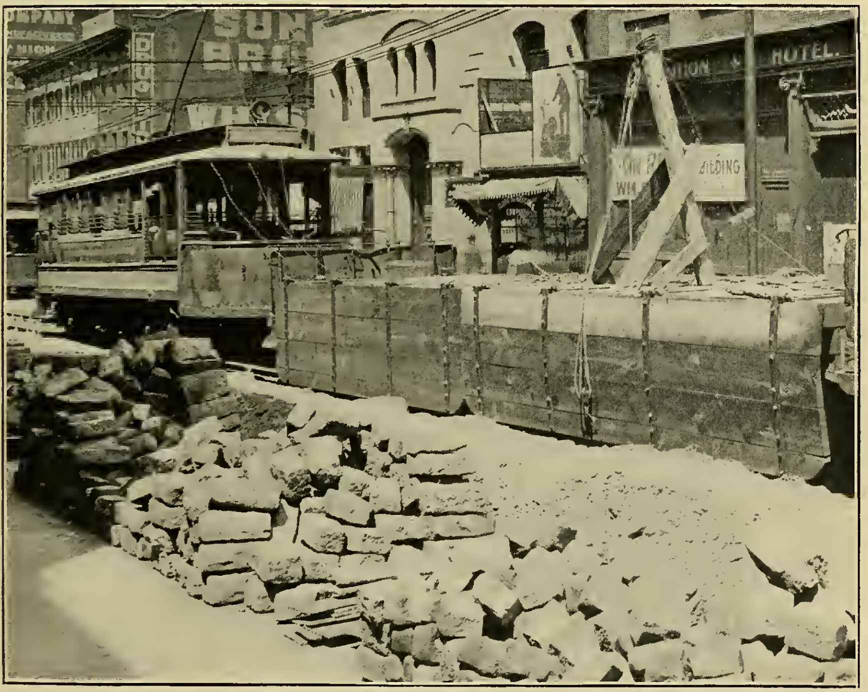


FIG. 7. COVER CAR USED FOR BLASTING IN OLIVE STREET.

Fig. 8. Blasting Concrete in Olive Street.

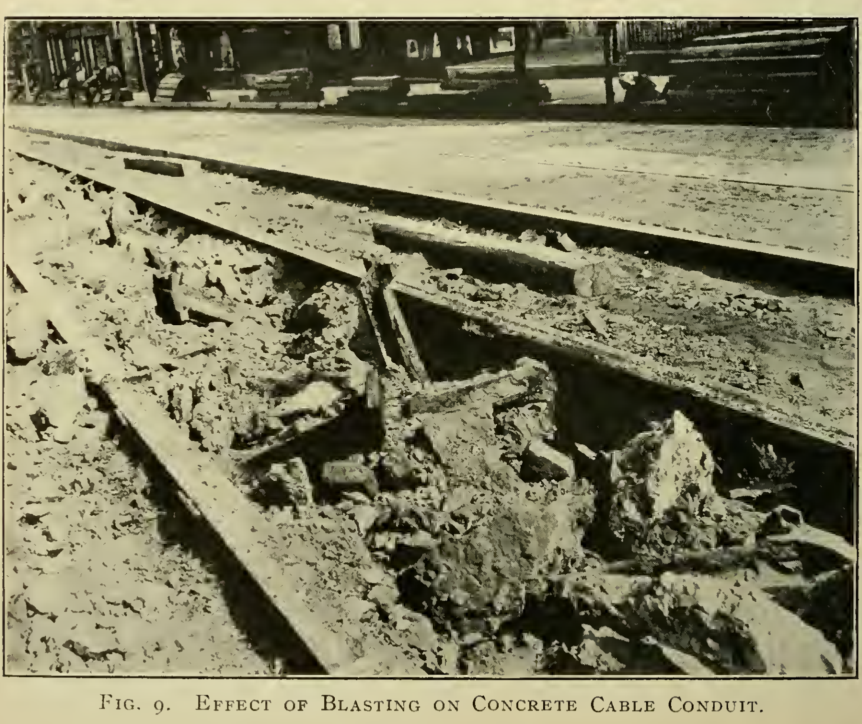


Fig. 9. Effect of Blasting on Concrete Cable Conduit.

broken by the force of the blast. Where these yokes had not been broken, they were knocked out by blows from pieces of rail. The efficacy of the blasting depended largely upon the proper location of the hole. Where the holes had been drilled close to the middle of the concrete block, so that the dynamite charge was exploded a little below the center of gravity of the section, the concrete was well shattered and could be picked out in large pieces. Where the hole had been located too close to either side of the concrete block, however, the charge would blow out at one side and a large mass of solid concrete would be left intact on the other side. The total estimated quantity of concrete blasted was 6 558 cu. yd., or 0.2 cu. yd. of concrete per lineal foot of track. The cost of the dynamite delivered in 0.1 lb. packages was 13 cents per pound. The exploders cost $0.0255 each.

The following statistics represent the average work of the three gangs working on the west-bound track between Fourteenth Street and Boyle Avenue.

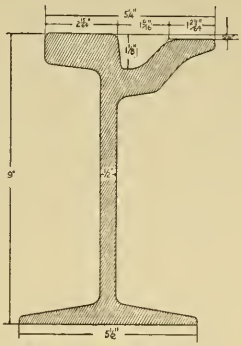
Cost of dynamite charge per hole	$0.013
Cost of exploder per hole	$0.0255

Four holes blasted in each four feet of track:

Lineal feet of track blasted per hour	138
Cubic yards of concrete blasted per hour	27.6
Cubic yards of concrete blasted per pound of dynamite	2
Labor cost per cubic yard, blasted	$0.076
Cost of dynamite and exploders per cubic yard, blasted	$0.192
Cost of labor and material per cubic yard, blasted	$0.268
Cost of blasting per lineal foot of track	$0.054
Cost of blasting per mile of track	$285.12
Cost of drilling and blasting per cubic yard	$0.353
Cost of drilling and blasting per lineal foot of track	$0.071
Cost of drilling and blasting per mile of track	$374.88

When the excavation was completed, the ties were placed in the trench, the rail spiked down, the tie rods pulled up to gage and temporary fishplates put on the joints. Work trains were then run on this track and the excavated material hauled away. The excavated material in this job amounted to 11 410 cu. yd., or 0.348 cu. yd. per lineal foot of track. The United Railways Company purchased a sink hole on North Grand Avenue and completely filled it with excavated material from Olive Street. All excavated material and all new material with the exception of the cement used in this work was handled on

cars, no teams being used at all. It would have been impossible to do the work in the time occupied had wagons and teams been depended upon.



United Railways Co. of St. Louis.
Section of 9" 112 lbs. Trilby Rail.

RAIL.

The rail used in this work was Lorain section 333, furnished in lengths of 60 ft. A cross-section is shown in the figure. The standard section has $\frac{7}{16}$-in. web, but it was considered desirable to have it rolled with $\frac{1}{2}$-in. web, and the rail with this change weighs 112 lb. per yd. Its height is 9 in., and the base is $5\frac{1}{2}$ in. The composition of the rail is as follows:

Carbon	0.55 per cent.
Silicon, not to exceed	0.20 per cent.
Phosphorus, not to exceed	0.10 per cent.
Sulphur, not to exceed	0.10 per cent.
Manganese	0.80 to 1.20 per cent.

This carbon is unusually high, as girder rail of this weight seldom is rolled with carbon to exceed 0.45 per cent. The increase in carbon makes the rail much harder, but also much more likely to break. No trouble has been experienced from this source, however, only one rail having been broken in unloading. The head is what is known as the Trilby type, having a groove for the wheel flange and a turned-over lip for the street traffic. It is a very desirable rail head for street traffic, as vehicles can cross it without bumping, but any rail with a wagon tread has an extremely limited life. The depth of the groove in the rail is $1\frac{1}{8}$ in. The flange of the car wheel is $\frac{5}{8}$ in. deep. Therefore, whenever $\frac{1}{2}$ in. is worn off the head of the rail, the wheel is running on its flange and the rail is worn out for railway purposes, although it may be in perfect condition otherwise. This merely demonstrates the advantage of the T-rail, the use of which is unfortunately prohibited by our city ordinances.

TIES.

The ties were of hewn cypress, 6 in. by 8 in. in section and 7 ft. long. It has been the usual practice in St. Louis to use white-oak ties, but it was considered that a soft wood tie en-

tirely embedded in concrete would be just as satisfactory as a hard wood tie. The ties were spaced two feet between centers. Tie plates were used under the rail, each alternate tie plate being a brace plate.

Concreting.

After the excavated material had been hauled away and the street cleaned up, the track was lined and surfaced by means of wooden blocks and wedges placed beneath the ties. Concrete was then tamped beneath and around the ties, the concrete being deposited in the track from a concrete mixing machine running on the rails. The concrete used was composed of a mixture by volume of one part of Portland cement, 2½ parts of river sand and 6½ parts of crushed limestone rock. The cost (delivered) of the materials composing this concrete was as follows:

Crushed rock	$2.85 per square	= $0.0285 per cu. ft. = 0.77 per cu. yd.
Sand	$2.50 per square	= 0.025 per cu. ft. = 0.675 per cu. yd.
Portland cement	$1.70 per barrel	= 0.425 per sack.

For the track work, 7.36 cu. ft., or 0.273 cu. yd., were required per lineal foot of track, 1¼ sacks of cement per lineal foot of track, or 1 650 barrels of cement per mile of track, were used in this work.

The value of the materials used (cement, rock and sand) was $0.108 per cu. ft. of concrete, or $2.92 per cu. yd. of concrete.

The material for the concrete was distributed on the street beside the tracks in advance of the machine, the sand being first deposited, then the crushed rock piled on that, and finally the cement sacks emptied on top of this pile. The materials were shoveled from this pile into the concrete mixing machine without any attempt at hand mixing on the street. Great care was taken in the delivery of materials on the street to have exactly the proper quantity of sand, rock and cement, so that there would be enough for the ballasting of the track to the proper height and that none would be left over. Each car was marked with its capacity in cubic feet, and each receiver was furnished with a table by which he could easily estimate the number of lineal feet of track over which the load should be distributed.

Concrete Mixing Machines.

The concrete mixing machines were designed and built in the shops of the United Railways Company. Three machines were used in this work, one for each gang. The machine is composed of a Drake continuous worm mixer, fed by a chain dragging in a cast-iron trough. The trough is 36 ft. long, so that there is room for fourteen men to shovel into it. Water is sprayed into the worm after the materials are mixed dry. This water was obtained from the fire plugs along the route. In the first machine built, the Drake mixer was 8 ft. long. In the two newer machines the mixer was 10 ft. long. Both the conveyor and the mixer were motor driven, current being obtained for this purpose from the trolley wire overhead. Two types of machines were used, one in which the conveyor trough was straight and 45 in. above the rail, and the other in which the conveyor trough was lowered back of the mixer, being 25 in. above the rail. The latter type had the advantage of not requiring such a lift in shoveling, but the trough is so low that a motor truck cannot be placed underneath it. In the high machine the mixer is moved forward by a standard motor truck under the conveyor. In the low machine the mixer is moved by a ratchet and gear on the truck underneath the mixer. A crew of twenty-seven men is required to work each machine, and under average conditions concrete for 80 lineal feet of single track, amounting to 22 cu. yd., can be discharged per hour. The following figures give the average performance of the three machines in concreting the westbound track from Fourteenth Street to Boyle Avenue:

Number of men employed at machine	27
Number of men shoveling into machine	14
Lineal feet of track concreted per hour	80.95
Cu. ft. of concrete discharged per hour	595.79
Cu. yd. of concrete discharged per hour	22.06
Labor cost of concrete per lineal foot of track	$0.071
Labor cost of concrete per cu. yd.	$0.26
Cost of materials composing concrete per lineal foot of track	$0.791
Cost of materials composing concrete per cu. yd.	$2.92
Total cost of concrete (labor and material) per lineal foot of track	$0.862
Total cost of concrete (labor and material) per cu. yd.	$3.18
Total cost of concrete (labor and material) per mile of single track	$4 551.36

In these figures there is no charge for electric power or for depreciation.

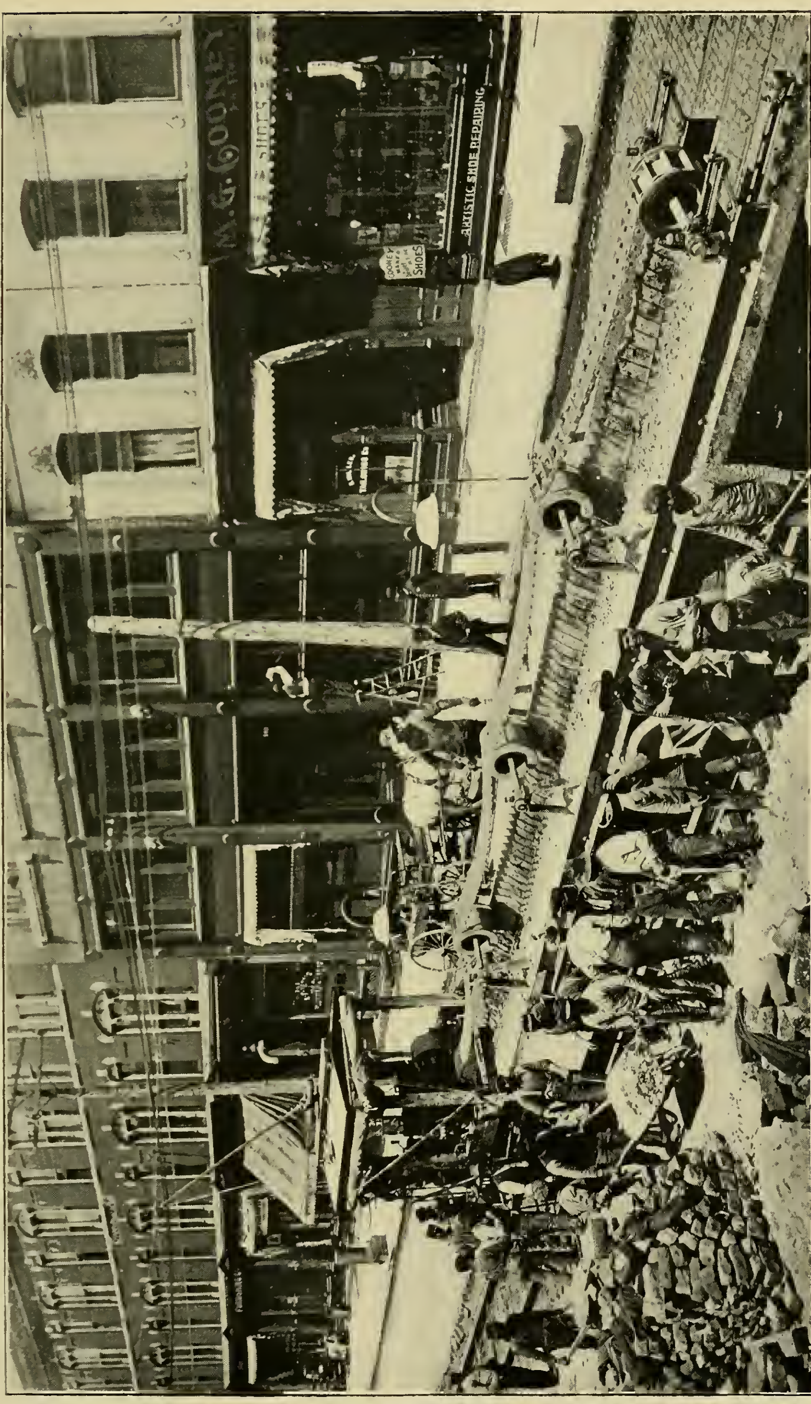


FIG. 11. HIGH CONCRETE MIXING MACHINE.

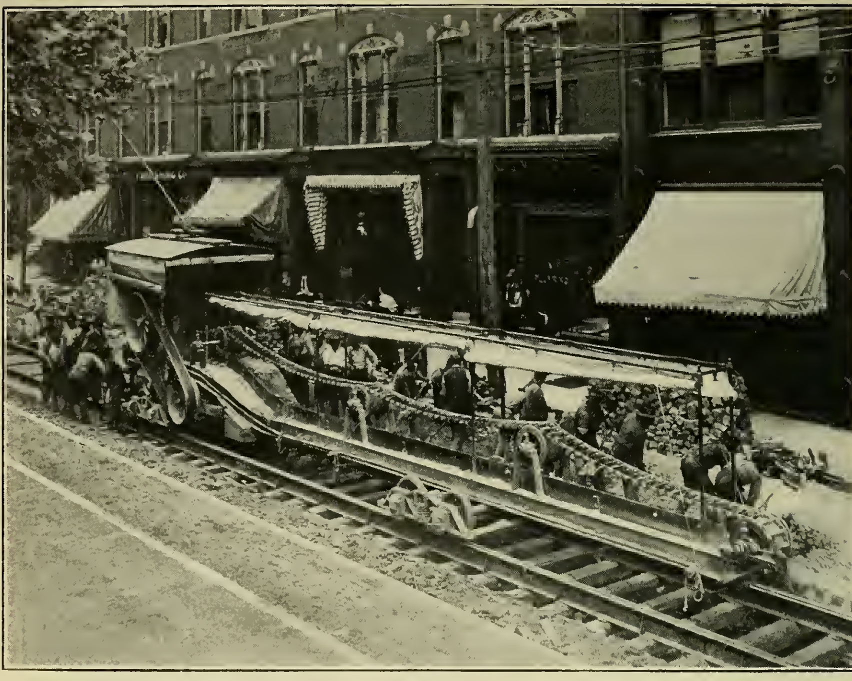


FIG. 12. LOW CONCRETE MIXING MACHINE.

FIG. 13. LOW CONCRETE MIXING MACHINE. DISCHARGING END.

Fig. 14. Track Lined and Surfaced, ready for Concreting.

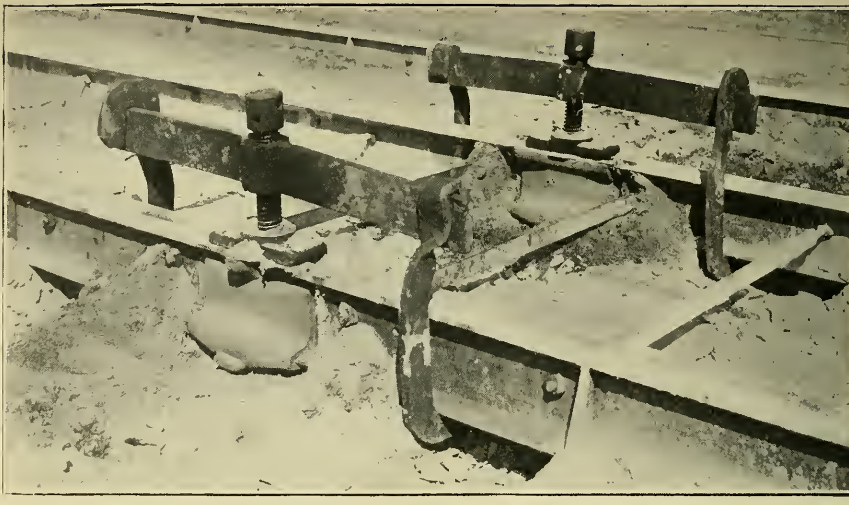


Fig. 15. Cast Weld Joint, before Removing Clamps.

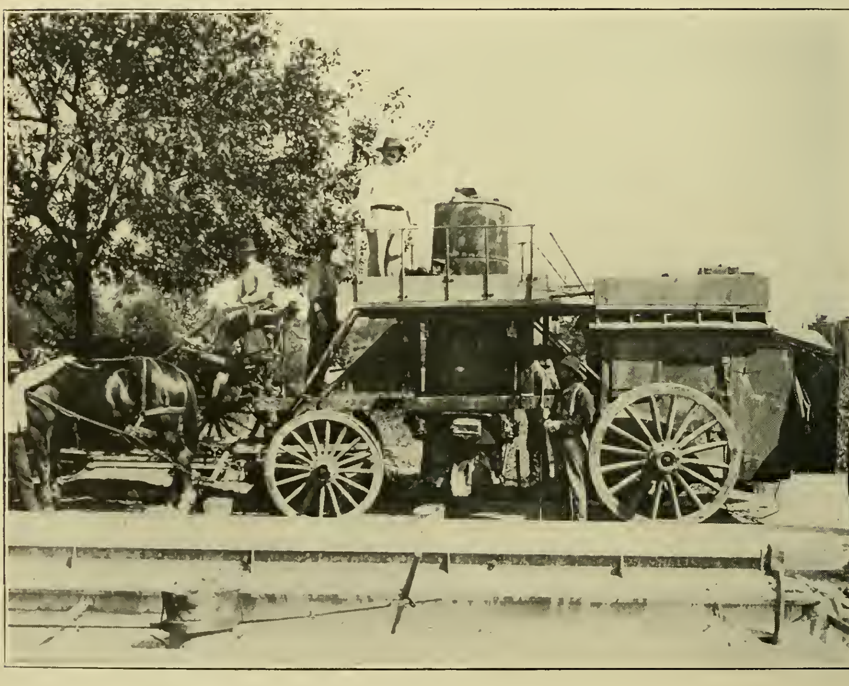


Fig. 16. Portable Cupola for Cast Welding.

Joints.

The rail joint adopted for this work was the cast-welded joint. This joint has been in use since 1896, the first use of it having been in this city. This method of joining rails has been the occasion of considerable debate among street railway engineers, the process having warm adherents and just as warm opponents. Without entering into a discussion of the matter, it will suffice to say that the process, when properly and carefully carried out, will produce excellent and permanent joints, and has the advantage of a reasonable cost where the work is done by the railway company as in this case. The process is an extremely simple one and consists merely in pouring melted cast iron into an iron mold placed around the abutting rail ends. The iron is allowed to harden, the molds knocked off and the joint is finished.

In performing the work, the fishplates which were temporarily placed on the joints for the lining and surfacing of the track are taken off and the rail ends thoroughly cleaned by means of a sand blast. Iron molds are then placed about the joint, a heavy screw clamp placed on the rail to keep it in perfect surface during the operation and melted iron poured into the mold. The iron is melted in a portable cupola, and consists of a mixture of one third selected scrap and two thirds soft charcoal iron. The secret of success with this process consists in thoroughly cleaning the rail ends, removing every particle of oxide, and in having the iron intensely hot when poured. Where these two precautions are taken, an actual welding takes place between the cast iron and the steel, a joint sawed in two showing an eating away of the base of the rail where the melted cast iron has struck it. Good joints have an electrical conductivity equal to, if not greater than, the same length of rail.

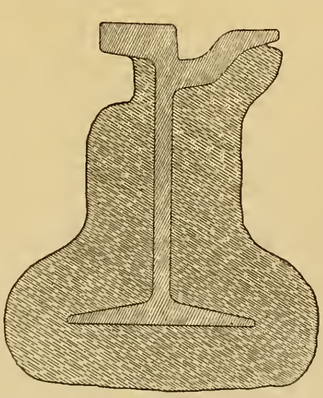


Fig. 17.

Objections have been made to this process on account of the heating of the head of the rail, it being stated that this heating anneals and softens the rail and causes it to wear away at this point. To prevent any annealing action, the molds used by the United Railways Company are so shaped that the cast iron is kept low on the back of

the rail, thus minimizing the heating of the rail head. The cast-iron joints used on the 9-in. rail shown in Fig. 17 weigh 170 lb., and the cross-sectional area is 65 sq. in. Assuming a tensile strength of 15 000 lb. per sq. in. for cast iron, the tensile strength of the joint is 975 000 lb., which indicates that the joint is stronger than the rail.

It is a source of wonder to laymen that miles of track in paved streets may be welded without any allowance for changes in length due to changes in temperature, and the question is often asked what becomes of the expansion and contraction of the rail. In answering this question, it should be remembered that the rail is embedded in a paving which soon packs so closely that any motion of the rail would be attended by great frictional resistance, and also that only 20 per cent. of the perimeter of the rail is exposed to the air, the rest of the rail being surrounded by a poor conductor of heat, so that the changes in temperature of the rail are not so violent nor are the extremes so great as those of the atmosphere. Nevertheless, there is a strain in the rail due to changes in temperature, and if there is no longitudinal motion to the rail, this strain is probably taken up in an infinitesimal change in the cross section of the rail.

In order to estimate what this strain amounts to, let us assume that the maximum deviation from the welding temperature is 75 degrees fahr., which is approximately correct for this climate. Assuming a coefficient of expansion of 0.000 000 5 for steel, a rail would contract, for a decrease of 75 degrees, 0.000 006 5 by 75, equal to 0.000 487 5 of its length. Assuming a modulus of elasticity of 30 000 000, this would correspond to a strain of 14 625 lb. per sq. in., which is well within the elastic limit of steel, showing that no harm is done by the alternate strains of tension and compression due to changes in temperature. As the cross-section of the rail is 11.2 sq. in., the pull in the rail due to contraction would be 11.2 by 14 625, equal to 163 800 lb., which is well within the tensile strength of the rail and the cast-welded joint.

Paving.

The last process in the track construction was the paving. Olive Street east of Grand Avenue is a granite street, and the track was paved with granite blocks resting on a sand cushion 1 in. deep. West of Grand Avenue the street was asphalt, and the tracks were paved with 3 in. of asphalt laid on the concrete,

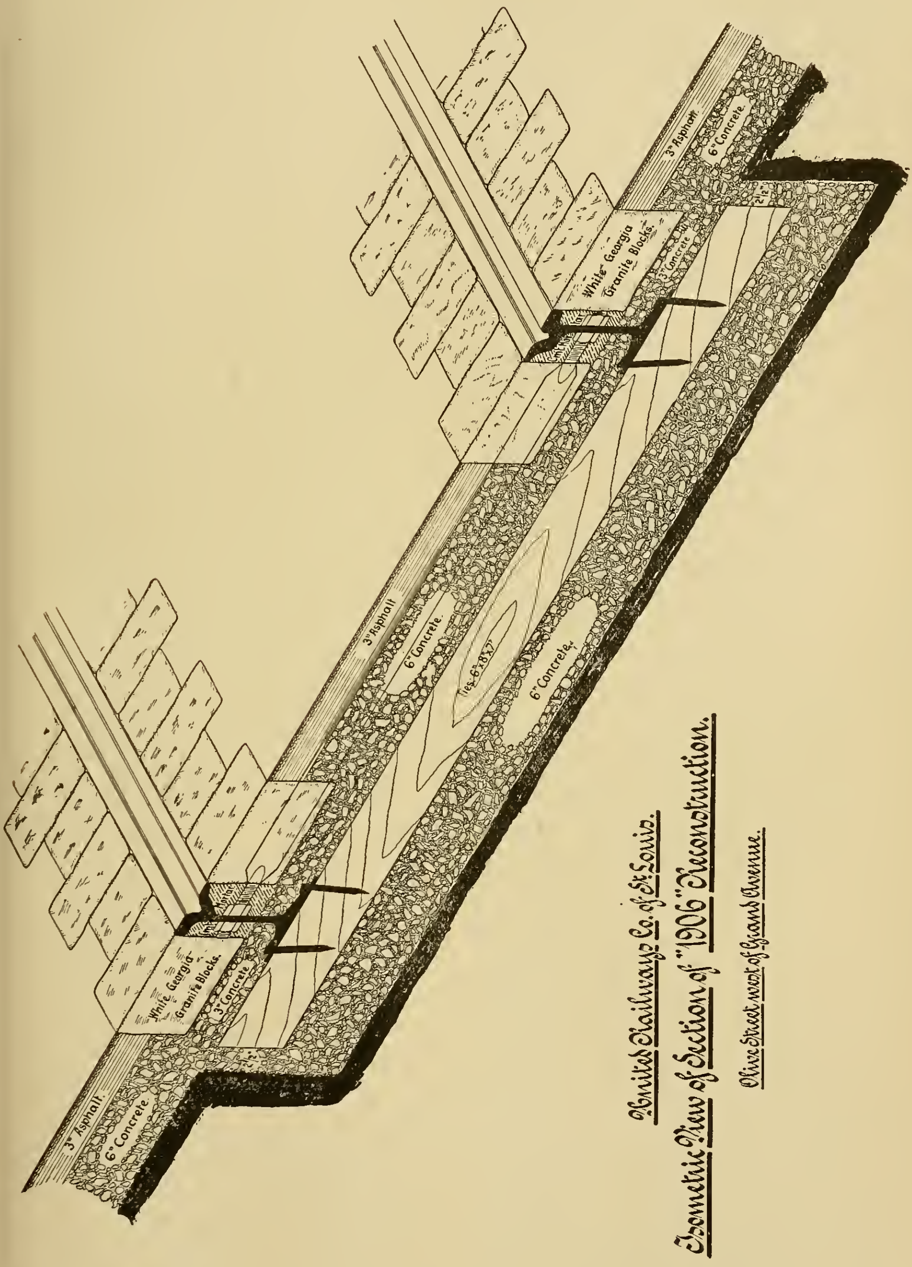

United Railways Co. of St. Louis.
Isometric View of Section of "1906" Reconstruction.
Olive Street west of Grand Avenue.
3" Asphalt.
6" Concrete.
White Georgia Granite Blocks.
3" Concrete.
Ties 6"x8"x7'
6" Concrete.
2½"

FIG. 18.

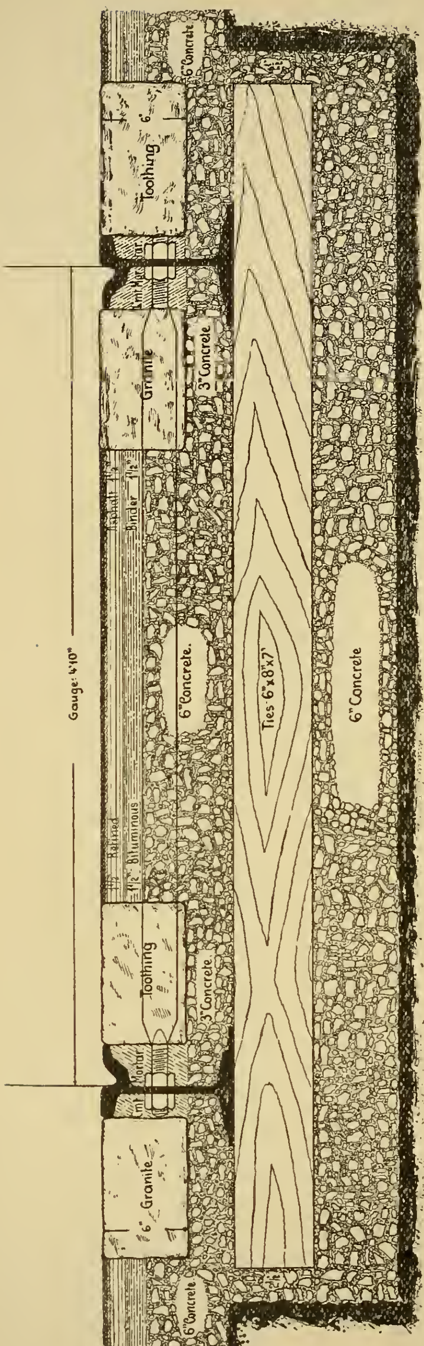


Fig. 19.

the asphalt being finished up against granite blocks set next the rails. This construction makes a smooth and sightly pavement. In all cases both sides of the rail were plastered underneath the head with a cement mortar, so that the paving blocks rested against a vertical surface and were prevented from sliding under the head of the rail. A cross-section of the finished track is shown in adjacent Fig. 19. and an isometric view in Fig. 18.

After the concrete work was finished, the concrete was allowed seven days to set before cars were allowed to run over it. This interval sufficed for the paving, so that the track was entirely finished before it was opened for traffic.

Speed of Construction.

The United Railways Company officials are especially proud of the speed with which this difficult work was performed. For the section between Fourteenth Street and Boyle Avenue (5.51 miles), work was begun April 30, 1906, and the cars were turned back on the street on June 11, 1906, exactly six weeks having elapsed

since ground was broken. Of this time, two weeks were allowed for the setting of the concrete, so that the entire work, with exception of the paving, was done in four weeks, which is an average of 1 040 lineal feet of single track (0.20 miles) per day. The cost of this $5\frac{1}{2}$ miles of track was about $170 500. For the entire work, after making the credits for scrap material from the old track, the average cost per mile of completed track was about $27 000.

Durability of Track.

In the track construction adopted by the United Railways Company only the best materials are used, and by the use of a concrete foundation it is hoped to obtain the most substantial and durable construction possible, and one which will maintain the street paving in good condition. The question is often asked how long such a track as that laid on Olive Street will last. Of course the wear on a track is directly proportional to the number of cars run over it. As has already been stated, the type of rail used in this construction is worn out for railway purposes when the wheel flange runs on the rail, which will occur when about $\frac{3}{4}$ in. is worn off the head of the rail. It is hoped that with the rail supported so firmly as in this case, so that there is no deflection as the car wheel passes over it, the rail wear will be minimized, but with the heavy traffic of this street, it is doubtful if the rail will have a life of more than ten years. The roadbed itself, however, should outlast several sets of rails. The ties are entirely embedded in concrete and are not subject to decay, and it is proposed that when the present rails are worn out, new rails shall be put down on the same roadbed, making the matter of renewing the rails a comparatively inexpensive process.

[Note. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by November 15, 1906, for publication in a subsequent number of the Journal.]

OBITUARY.

Eddy Elbert Young.

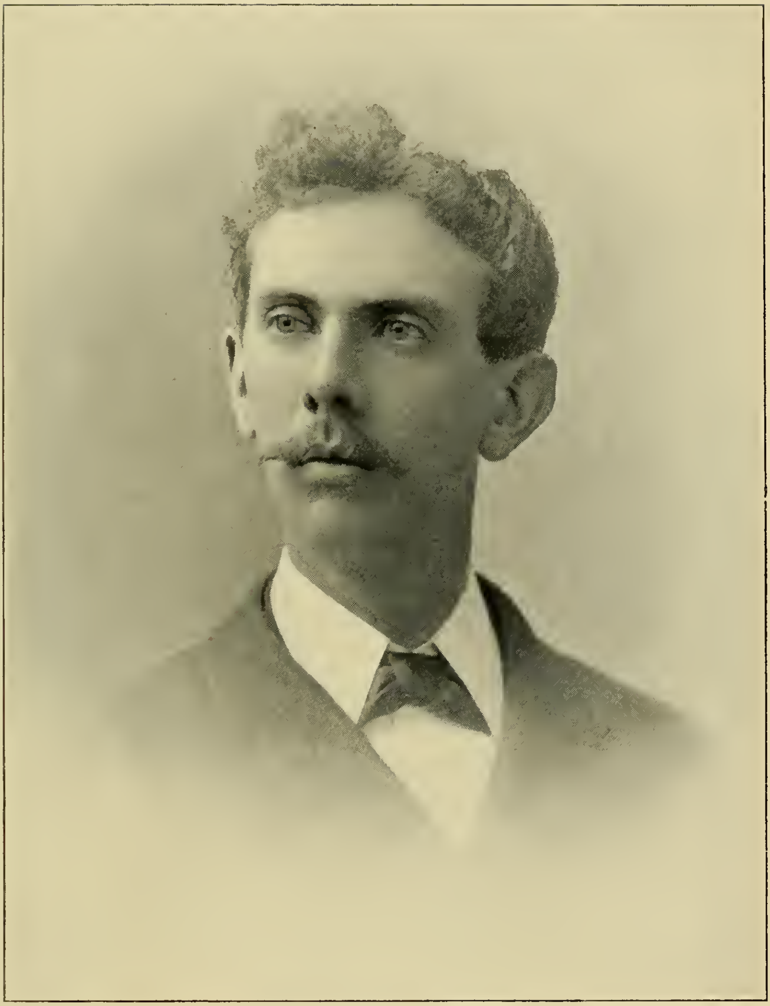
MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

EDDY ELBERT YOUNG, son of Enoch Young and Cordelia Young, was born in 1865 in Wapun, Wis. In 1867 his parents took him from Wapun to Lowell, Mass., in which city he spent his boyhood.

As will be seen in the outline of his professional work given below, he began at the age of sixteen. He had then gone only partly through the Lowell High School, but after he started work he continued his schooling by studying mechanical and architectural drawing for several winters in an evening class. He was quick of apprehension and thus got more than most boys from his brief schooling. His choice to leave school at the early age he did was later a source of regret. His regret was, to a considerable degree, needless, for by his private study and his close and accurate observation he became in many respects a man of culture as well as an advancing engineer. At the time of his early death he had already done much good work and showed every indication of doing even better.

The following is an outline of his professional career, the account being, in part, taken from the information furnished at the time of his becoming an associate member of the American Society of Civil Engineers:

Spring and summer, 1881, draftsman and rodman, Merrimack Manufacturing Company (mill engineering): May, 1883, to April, 1884, draftsman and rodman with Melvin B. Smith, C.E. and Surv.: remainder of 1884, draftsman and transitman on short engagements of a miscellaneous character: March, 1886, to May, 1888, draftsman and transitman, New York & New England Railroad: September, 1888, to March, 1889, draftsman, transitman and inspector, Boston & Maine Railroad, on construction, Mystic terminal grounds: summer, 1889, assistant with George H. Barney, C.E. and Surv., Hyde Park, Mass.: autumn 1889, to spring, 1890, assistant and inspector with Percy M. Blake, C.E., on construction, Andover Water Works, Andover, Mass.: spring and summer, 1890, assistant with city of Newton



Eddy Elbert Young.

(Albert F. Noyes, city engineer), on assessors' maps, drafting, surveying, computing, etc.: September, 1890, to October, 1894, draftsman and transitman, Metropolitan Sewerage Commission of Massachusetts, office, surveys and construction of North Metropolitan and Charles River systems, including compressed air tunnel work, etc.: October, 1894, to March, 1898, assistant engineer, Boston Transit Commission, on Boston subways, designs for ventilating chambers: grading, sewers, etc., for Boston Common: tunnels under thoroughfares; pile foundations, Public Garden incline: April, 1898, to January, 1899, assistant engineer, on sewer assessment, city of Boston; February to April, 1899, assistant engineer, Boston Elevated Railway on designs for masonry structures: June, 1899, to August, 1903, assistant engineer, Metropolitan Sewerage Commission of Massachusetts, on high-level sewer, surveys, mapping same, tunnel construction in rock and earth (compressed air used to advance headings in quicksand): August, 1903, to June 30, 1904, engineer of alignment on Hudson Tunnel, in charge of triangulation, lines, grades, etc., under Jacobs & Davies, consulting engineers: August, 1904, to January 31, 1906, in charge of drafting for the O'Rourke Engineering Construction Company, New York City: February 1, 1906, to the time of his death, June 1, 1906, engineer and manager of the New York work of the Healey Sewer Machine and Construction Company, land and subaqueous borings for various railroads, the New York Rapid Transit Railroad Commission and for the additional water supply for New York.

It is pleasant to recall that the excellent character of Mr. Young's work was meeting with substantial reward. An instance of this was the bonus of $500, with which he was presented by his employers, Messrs. Jacobs & Davies, on the meeting of the Hudson River Tunnel headings for whose alignment he was responsible. The letter of transmittal, which also informed him of an increase in salary, spoke of the check as "some appreciation" of the value of Mr. Young's work and the untiring energy he had always shown in the interests of the tunnel company.

February 6, 1897, he married Miss Alice Frances Carter, of Charlestown, Mass., who survives him with their two children.

Mr. Young's physical condition, for some years prior to his death, had been such as to call for a serious surgical operation. His very energy and ambition here worked against him, leading him to delay too long in seeking surgical relief. In April, 1906, however, he came back to Boston, where the necessary operation

was performed on the 6th of that month in a private hospital. On the 25th of April he went back to business in New York, but at the end of two days he was forced to leave off. He returned to his home in Auburndale, May 19, and his death occurred in that town. The immediate cause of his death was acute nephritis, but the original cause was his extreme devotion to work which led him to forget himself too completely.

The burial was in Lowell, Mass.

Mr. Young's tastes were fine, as evinced by his fondness for music, his talent for artistic drawing and modeling, and his appreciation of the beautiful in form and color.

Many will feel that by his death they have lost a valued friend. The engineering profession has lost a member who was ambitious and who was earnest in whatever he undertook and who did all his work with honesty, truthfulness and ability.

H. A. Carson.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXXVII. SEPTEMBER, 1906. NO. 3.

THE RELATION OF THE SUSPENDED MATTER IN SEWAGE TO THE PROBLEM OF SEWAGE DISPOSAL.

BY HARRISON P. EDDY AND ALMON L. FALES.

[Read before the Sanitary Section of the Boston Society of Civil Engineers, October 3, 1906.]

ONE of the most troublesome features of the problems relating to the disposal of sewage is the control or removal of the matters carried in suspension.

An early consideration, and one of no mean importance in the design of a sewer system, is that of affording conditions which will insure the conveyance of solid particles regularly with the flow of the sewage. This is accomplished, as is well known, by means of the slope given to the sewers, which is so regulated as to provide a velocity of flow sufficient to carry these matters in suspension. Where such slope cannot be had for topographical reasons various substitute methods are provided to accomplish the same purpose.

Again, in pumping, special and often elaborate provisions are made for removing from the sewage the sand and coarser matter in suspension for the preservation and effective maintenance of the machinery.

In the discharge of sewage into water courses, lakes and tide-waters, an important consideration is the effect of the solids which float upon the surface of the water or which settle to the bed of the stream or the bottom of the lake or bay.

The problems of sewage treatment are naturally separated into two general groups,— those dealing with the liquid and soluble portion, and those having to do with the solids floating or carried in suspension.

It has come to be very generally recognized that the latter group of problems constitutes the more difficult and expensive part of the treatment. With the satisfactory solution of such questions sewage disposal would be very greatly simplified.

It is the purpose of this paper to present some of the results of the practical operation of various methods of sewage purification at the disposal works in the city of Worcester, Mass., with the view of placing on record some information bearing directly upon this subject.

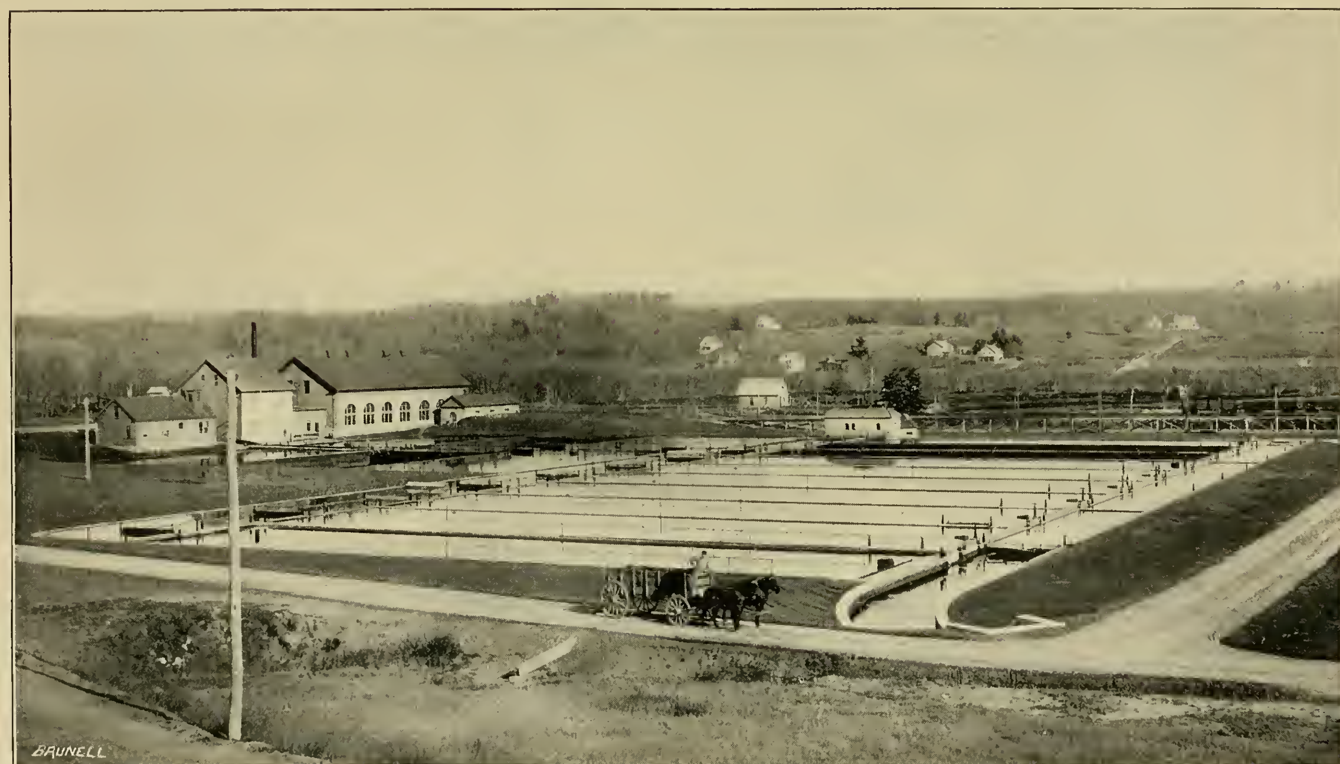
In 1890 a small chemical precipitation plant was put into operation, consisting chiefly of six settling basins, lime house, power plant and laboratory. This equipment was designed to treat about 3 000 000 gallons per day. In 1893 the number of settling basins was increased to 16, each holding 350 000 gal.

The first sewers were built under special authorizing statute in 1867, and from that time until 1901 the sewage was discharged into a natural stream passing through the city from north to south, and having a watershed above the sewer district of about 7 sq. miles. This brook has for a number of years been controlled by a storage reservoir and the waters drawn in fairly uniform quantity for manufacturing purposes. The dry weather flow rarely dropped below 3 000 000 gal., with an average of about 5 000 000 gal., while occasionally the spring discharge ran up to 60 000 000 or 70 000 000 gal. per day.

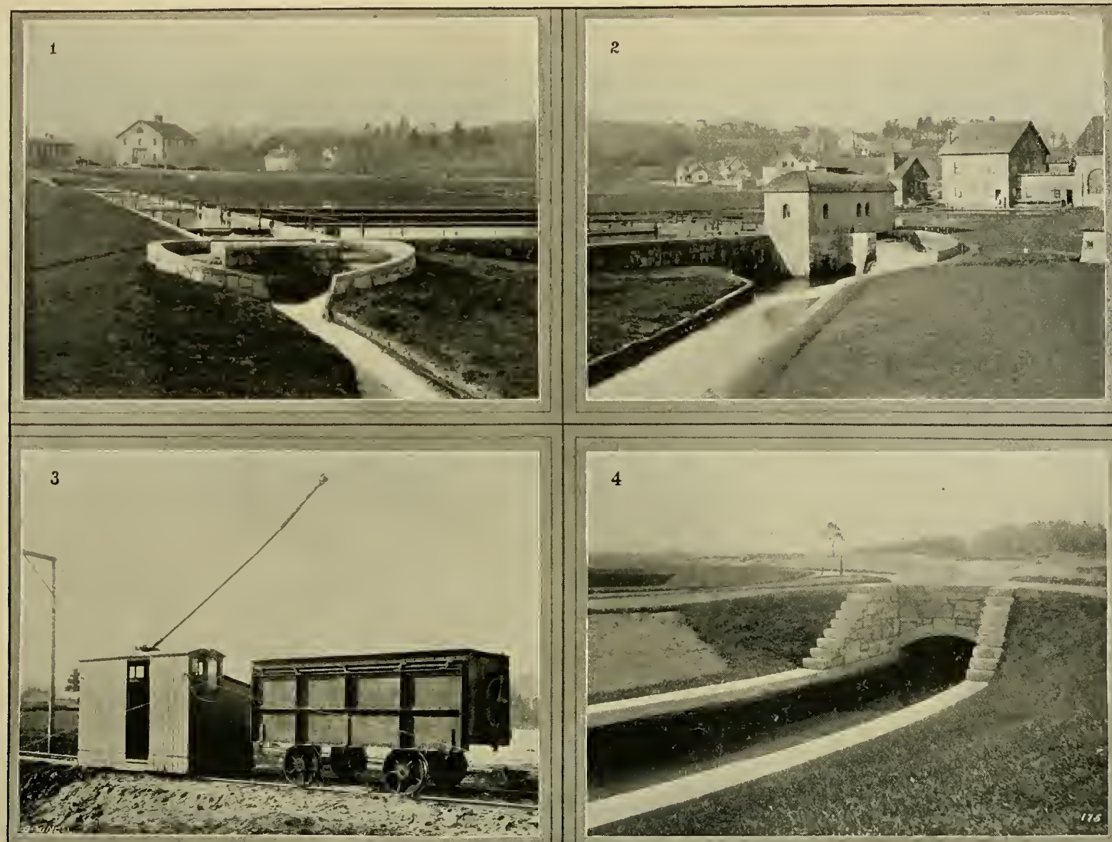
At the time the disposal plant was built the sewer system was almost wholly on the combined plan, the drainage area being about 5 sq. miles. With the 16 settling basins the dry weather flow of sewage, amounting to about 16 000 000 gal. daily, could be treated, but any material increase in flow, due either to storm water or to greater draft from the controlling reservoir on the brook, caused an overflow into the river of water which could not be taken to the purification works because of the limited capacity of the outfall sewer.

For a number of years the sludge, resulting from the chemical treatment, was pumped directly from the settling basins on to adjacent fields, where it was allowed to drain and dry. Some of it was used for fertilizer and some burned, but a very large amount simply remained where it was delivered by the pump and is still on hand, although grassed over and yielding a profitable crop of hay each year.

This method of sludge disposal being unsatisfactory in many ways, a sludge pressing plant was built in 1898. With this machinery the sludge has been pressed immediately after pump-



Precipitation Plant, Worcester, Mass.



Views at Purification Works, Worcester, Mass. 1. Spillway. 2. Spillway and Compressor House. 3. Motor Car with Sludge Car Attached. 4. Entrance to Conduit Leading to Filter Beds.

ing, and hauled by electric cars to a dump about three quarters of a mile away.

Worcester maintained an average growth during 50 years amounting to an increase of about 20 per cent. of its population every 5 years. This rate of growth has not been maintained, however, during the last 5 years, according to the state census.

Increasing size has required the continued enlargement of the water system, and thus far all the water supplied to the city has been taken from streams tributary to the Blackstone River, into which the sewage is discharged after treatment. The river above the purification works has accordingly decreased in size from year to year, thus furnishing a smaller quantity of pure water for dilution of the sewage and sewage effluents.

In 1901 two intercepting sewers were completed and now receive the sewage through automatic regulating gates. In time of storm, after the outfall sewer becomes filled to its capacity, these gates allow the surplus of storm water and sewage to overflow into the brook. This overflow of untreated sewage occurs only in time of actual storm or melting snow.

From the time when it was decided to build a plant for sewage treatment, all new sewer districts have been provided with the separate system, and at the present time the sewer system consists of 72.95 miles of separate sewers, 62.248 miles of combined sewers, these two systems being tributary to the disposal works; and 41.607 miles of surface water drains having no connection with the outfall sewer.

The small flow of the Blackstone River (drainage area, 57.07 sq. miles) and the increasing proportion of sewage effluent made it evident that eventually it would be necessary to treat the sewage more thoroughly than was possible by means of chemical precipitation, and accordingly the city began the construction of sand filters in 1898 and has increased this part of the plant from time to time, until there are now 36 acres of actual filtering area.

These filters have received crude sewage and the effluents from the chemical and septic treatments, and from simple sedimentation.

All of the processes which have been used on a practical scale have been affected by the solids suspended in the sewage. In each case a waste material has been produced consisting of liquid sludge resulting from the preliminary treatments, and of dry or nearly dry accumulations on the filters.

The sewage received at the disposal works contains large quantities of manufactural wastes, the most important being that from the tanneries and from various wire-drawing establishments. A fair idea of the quality and quantity of sewage dealt with during the past twelve years may be obtained by an examination of Table I.

About one third of the total residue on evaporation is suspended matter, and of the suspended matter one half to two thirds is organic and volatile.

The figures for solids for 1901, 1902 and 1903 given in the table are taken from the analyses of the sewage entering the septic tank, and as all storm water was carefully excluded the suspended solids are somewhat lower and the proportion of organic and volatile matter somewhat higher than the average sample of all sewage would give.

It will be noticed that the suspended albuminoid ammonia is usually higher than the dissolved. This difference becomes more marked during the last five years, which may be explained largely by the fact that the intercepting sewers were in use. Previous to this time large quantities of the suspended solids settled out of the sewage during its passage through the brook channel into which it was discharged and from which it was diverted into the outfall sewer by means of a dam. At times of high water the increased velocity of flow in the brook carried much of the deposit directly into the river.

It is also true that beginning at about the same time analyses were made in weekly samples, made up of sterilized daily portions, and in spite of sterilizing more or less of the soluble and colloidal matters was precipitated.

Beginning with 1905, however, the samples were filtered as soon as taken, thus assuring accuracy in the determination of the proportion of suspended to dissolved solids.

Throughout this discussion the costs given include the entire cost of supervision, clerical services, laboratory expenses, including all experimental work, as well as the repairs on the plant, but do not include interest on the original investment.

Grit Chambers.

In 1904, 2 grit chambers were built, each being 10 ft. wide, 40 ft. long and providing for a depth of about 9 ft. of sewage and silt. They were constructed side by side on the line of the 42-in. outfall sewer, and so arranged that the sewage could

TABLE I.

Analysis of Worcester Sewage.

(Parts per 100,000.)

Date.	Residue on Evaporation.									Ammonia.				Oxygen Consumed in 2 Min. at 100° Cent.			
	Total Residue.			Volatile Residue.			Total Residue.				Albuminoid.						
	Total.	Dissolved.	Suspended.	Total.	Dissolved.	Suspended.	Total.	Dissolved.	Suspended.	Free.	Total.	Dissolved.	Suspended.	Unfiltered.	Filtered.	Chlorine.	Average Flow Treated in Million Gallons per Day (365 Days).
July 19 to Dec. 1, 1893	62.8	43.5	19.3	28.3	16.5	11.8	34.5	27.0	7.5	1.395	.536	.266	.270	5.17	2.85	6.05	4.92
Year ending Dec. 1, 1894	60.4	37.4	23.0	23.3	12.5	10.8	37.1	24.9	12.2	1.073	.506	.248	.258	4.95	2.60	5.66	12.49
" " " 1895	Residue on evaporation not determined.									1.160	.518	.249	.270	5.27	2.91	5.98	15.70
" " " 1896										1.118	.497	.246	.251	4.63	2.47	5.50	16.00
" " " 1897										1.108	.478	.233	.245	4.23	2.12	5.87	17.00
" " " 1898										0.851	.438	.221	.217	4.03	2.17	4.76	17.68
" " " 1899										1.097	.480	.237	.243	5.63	3.24	5.87	17.10
" " " 1900										1.368	.527	.240	.287	6.99	4.75	6.78	13.10
" " " 1901	87.9	55.3	32.6	46.3	26.0	20.3	41.6	29.3	12.3	1.786	.632	.255	.377	8.83	5.81	7.21	9.77
" " " 1902	83.2	52.2	31.0	41.6	24.0	17.6	41.6	28.0	13.4	2.059	.810	.252	.558	11.02	6.83	8.43	13.27
" " " 1903	81.4	52.6	28.8	41.7	23.8	17.9	39.7	28.8	10.9	1.769	.832	.288	.544	9.39	5.36	9.04	15.55
" " " 1904										1.955	.840	.318	.522	10.05	6.15	10.23	12.63
" " " 1905	90.2	68.5	21.7	50.7	34.6	16.1	39.5	33.9	5.6	2.035	.926	.377	.549	11.96	7.54	11.64	11.83

be turned through one or through both at the same time, as was deemed best.

Experience has proved that with the ordinary flow of sewage, say up to 15 000 000 gal. per 24 h., too much organic matter is settled out if both basins are in operation. When storm water is mingled with the sewage, at which time the rate of flow is generally above 15 000 000 gal., it has been found necessary to allow the flow to pass through both chambers to insure the collection of substantially all of the sand and gravel.

Following is a schedule of some of the important statistics gathered from the operation of the grit chambers through a period of something over a year.

Grit Chamber Statistics.

	Customary Use of Chambers.	Two Chambers in Use at Rates below 15 000 000 Gal.
Deposit per million gallons sewage passed through chamber...	0.16 cu. yd.	0.52 cu. yd.
Cost of cleaning chambers and hauling refuse 1 000 ft.	$0.81 per cu. yd.	$0.95 per cu. yd.
Cost of cleaning chambers and hauling refuse 1 000 ft. (per million gallons sewage passed through basin)..............	$0.13	$0.51
Dry solid matter contained in refuse	50 per cent.	30 per cent.
Volatile (loss on ignition) matter contained in refuse...........	35 per cent.	50 per cent.
Organic nitrogen in dry solid matter......................	0.75 per cent.	1.00 per cent.
Weight of refuse as removed from chambers	67.2 lb. per cu. ft.	

In the consideration of the above figures it should be remembered that there was comparatively little storm water received during the year. This fact would probably not materially affect the amount of refuse per million gallons or the cost of removing the same, but would doubtless affect its weight and the proportion of mineral and organic constituents.

A very offensive odor was always given off from the sludge when it was being removed from the basins and for some time after it had been spread upon the dump. This is a matter deserving serious consideration when the location for grit chambers is to be selected.

No special machinery has been installed for handling this material, it being shoveled out of the basins by hand and hauled away in tip carts.

Removing Heavy Deposit from Precipitation Basin before Grit Chambers were Constructed, Worcester, Mass.

Sludge Resulting from Chemical Precipitation.

As has already been pointed out, Worcester sewage contains large quantities of pickling liquids. These are present to such an extent that they have a very material effect upon the sludge which is produced in the settling basins. The only chemical added to the sewage is lime, there being present at nearly all times sufficient copperas to insure a good treatment, although there is not always enough to completely remove the coloring matter when the sewage contains very large quantities of refuse from the tanneries and from the dye works. When the lime is added to the sewage the iron is thrown out of solution in the form of a flocculent precipitate. This settles to the bottom of the basins, together with the suspended matter carried in the sewage, and forms the sludge.

The amount of sludge formed depends not merely on the amount of suspended matter in the sewage, but is governed largely by the amount of dissolved iron present; consequently the amount and character of the sludge vary during different portions of the day and at different periods, depending on the condition of business in general, and particularly on that of the iron and steel industries.

During the first part of storms the sludge deposited is very heavy, owing to road detritus. The grit chambers which have recently been built retain much of this material, which is removed and taken directly to the dump. With this arrangement the sludge in the settling basins has become more uniform in character, and more easily pumped and pressed.

It is a well-known fact that the sludge resulting from chemical precipitation decomposes on standing in the same way as does the crude sewage sludge of the septic tank. During the warm weather the evolution of gas is quite violent unless the sludge is removed from the basins at frequent intervals. Portions of the sludge, which for a time retain the gas after it is generated, are carried to the surface, where a part remains, the rest settling again to the bottom of the basin. If this process is allowed to become very general throughout the basins the effluent resulting from the treatment will contain an abnormal quantity of suspended solids. It has been found advantageous to remove the sludge from the roughing tanks about once in two weeks, and from the finishing tanks about once in four weeks.

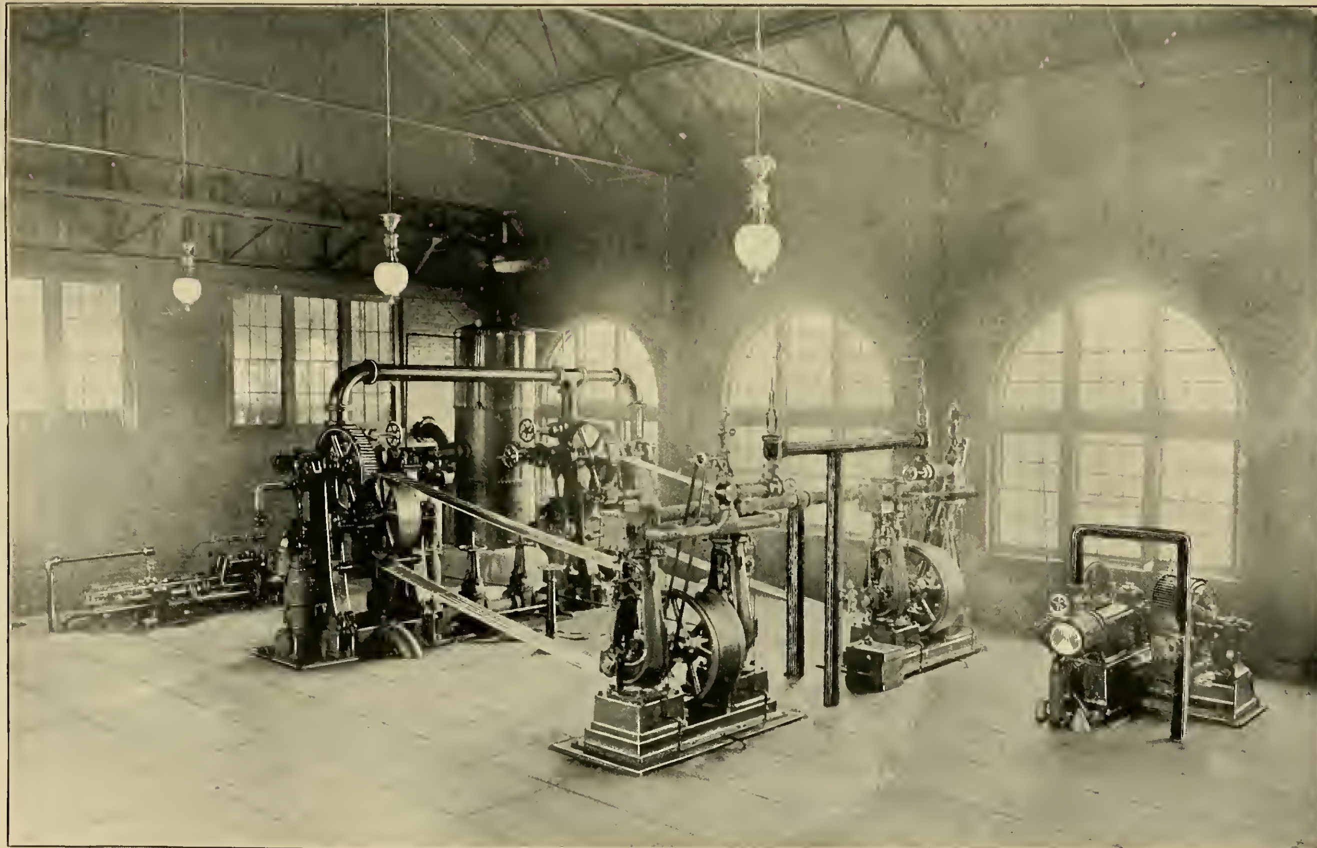
The following table is a compilation of various statistics collected during 15 years of the operation of the Worcester plant:

TABLE II.

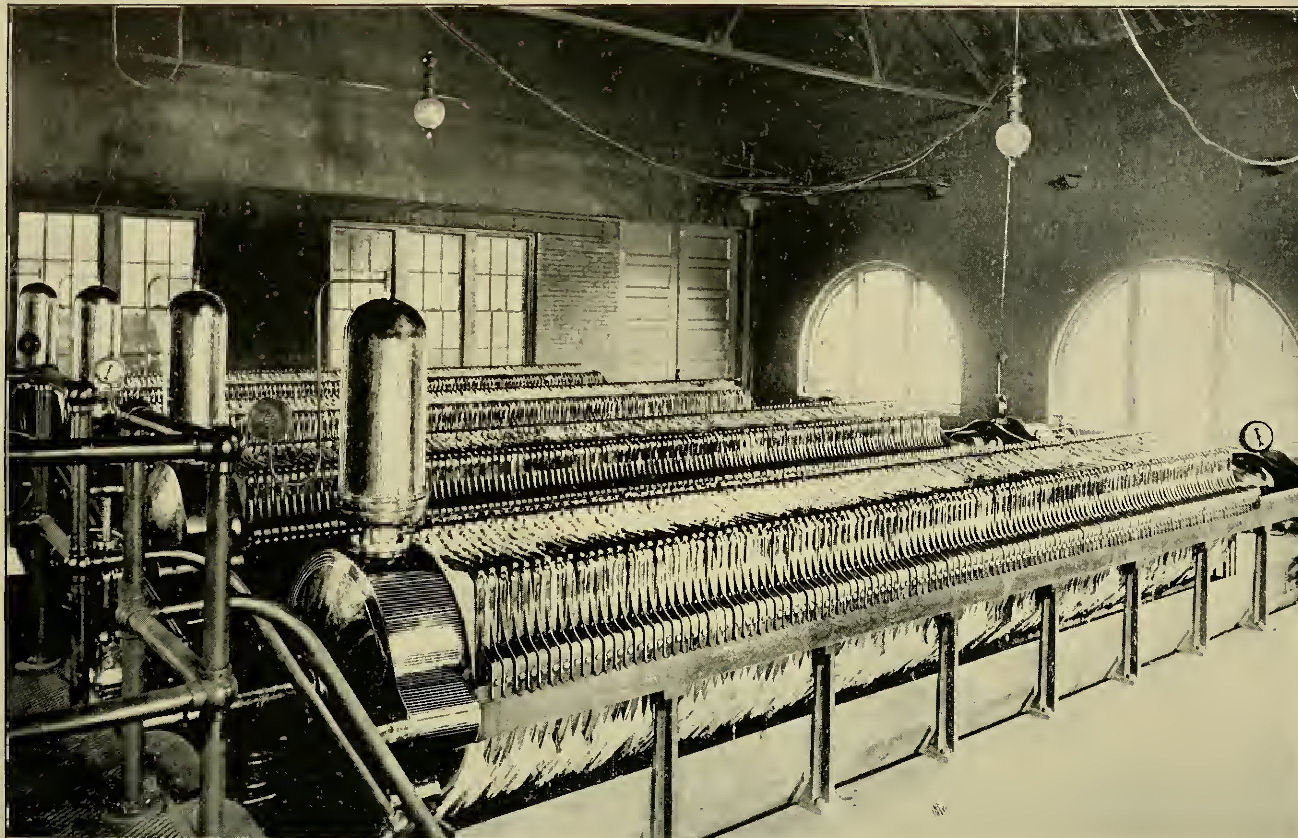
DATA ON SLUDGE RESULTING FROM CHEMICAL PRECIPITATION.

Year.	Average Flow of Sewage Treated in Million Gallons per Day (365 Days).	* Lime Used in Chemical Treatment Lb. per Million Gallons Sewage Treated.	Volume of Sludge Pumped from Settling Basins.		Solids in Sludge Pumped from Settling Basins.	
			Gallons per Million Gallons Sewage Treated.	Relation to Volume of Sewage Treated.	Per Cent. of Solids in Sludge.	Tons of 2 000 Lb. per Million Gallons Sewage Treated.
				Per Cent.		
1891	3.83	965	15 760	1.6	1.33	0.88
1892	2.30	1 079	13 780	1.4	1.33	0.76
1893	4.92	1 170	10 970	1.1	2.88	1.31
1894	12.49	941	10 280	1.0	2.88	1.23
1895	15.70	1 030	11 600	1.2	2.88	1.39
1896	16.00	1 212	11 060	1.1	2.61	1.20
1897	17.00	1 130	10 730	1.1	2.61	1.17
1898	17.68	1 073	7 820	0.8	2.61	0.85
1899	16.35	1 204	11 230	1.1	2.99	1.40
1900	10.10	1 373	11 260	1.1	4.42	2.08
1901	8.58	1 498	8 638	0.9	4.85	1.75
1902	12.54	1 005	4 935	0.5	7.41	1.52
1903	14.39	871	4 809	0.5	7.23	1.45
1904	11.55	1 005	6 392	0.6	6.24	1.65
1905	10.11	999	4 950	0.5	8.28	1.71

* Lime added to sludge to facilitate pressing not included.



Engine-room, Showing Engines and Pumps, Pressure Tank, Hydraulic Pump, and Direct Connected Engine and Dynamo, Worcester, Mass.



Sludge Filter Presses, Worcester, Mass.

The difference between the quantity of sewage treated in the years previous to 1900 and the following years is accounted for by the partial change from the combined system to the separate system, the completion of two main intercepting sewers, by means of which a large amount of brook water was excluded from the sewage, and a certain amount of untreated sewage turned directly on to the filter beds.

Sludge Pressing.

The sludge pressing plant consists of the necessary pumping machinery and 4 filter presses, each containing 125 circular chambers 36 in. in diameter and 0.75 in. wide. The sludge is pumped from the precipitation basins into storage tanks. After settling, the clear water is drawn off, and the sludge pumped by power plunger pumps into the filter presses under 80 lb. pressure to the sq. in. The presses are closed by hydraulic rams. The sludge cake is stripped from the filter cloths and allowed to fall into conveyors, which deliver it into cars. It is then hauled by motor car to a sludge dump located about three quarters of a mile from the press house. When sludge is very fresh, and consequently quite thin, the presses do not fill as rapidly as when it has become denser. It is, therefore, usually allowed to remain in the settling basins until it reaches a density of from 4 to 7 per cent. solids.

From 20 to 30 lb. lime per 1 000 gal. are required to facilitate the pressing of comparatively fresh sludge. As septic action becomes well established, however, the difficulty experienced in pressing is greatly increased, and much more lime is needed, reaching as high as 100 lb. per 1 000 gal. pressed.

Table III is a statement of the results obtained by the sludge-pressing plant during the 7 years in which it has been in use:

TABLE III.

Results of Sludge Pressing, 1899 to 1905.

Year.	Gallons Sludge Pressed per Day (365 Days).	Sludge Cake Produced.		Dry Solids in Cake.		Lime Added to Sludge to Facilitate Pressing.		Cost of Pressing, Hauling and Dumping Sludge.	
		Cubic Yards per Million Gallons Sewage Treated.	Tons of 2 000 Lb. per Million Gallons Sewage Treated.	Per Cent. of Dry Solids in Cake.	Tons of 2,000 Lb. per Million Gallons Sewage Treated.	Pounds per Thousand Gallons Sludge.	Pounds per Million Gallons Sewage Treated.	Per Million Gallons Sewage Treated.	Per Ton of Dry Solids in Cake.
1899......	144 100	6.2	5.3	26.1	1.07	11.1	93.6	$4.92	$4.64
1900......	108 100	8.7	7.4	28.0	1.98	21.2	226.6	6.76	3.42
1901......	68 280	7.6	6.5	27.0	1.75	20.0	159.7	5.89	3.39
1902......	57 270	5.7	4.8	31.6	1.52	30.3	149.6	5.20	3.41
1903......	67 200	5.6	4.8	30.3	1.45	33.5	161.1	4.91	3.39
1904......	66 660	6.8	5.7	28.9	1.65	28.5	180.1	5.83	3.51
1905......	45 070	5.9	5.3	32.2	1.71	53.5	265.1	6.33	3.71

Sludge Resulting from Plain Sedimentation.

During the years of 1902 and 1903 several experiments were made to ascertain the degree of purification attained and the quantity of sludge that would be deposited on passing sewage at different rates through a basin 40 ft. by 166.666 ft. by 7 ft. deep, holding about 350 000 gal. Cofferdams, 2 or 3 ft. high, were built across the basin, dividing it into four equal compartments. Directly above these were scum boards extending 18 in. below the surface of the water, and projecting above it about 8 in.

The sewage was admitted from a trough extending across one end of the basin, by means of apertures about 12 in. apart, and 18 in. below the surface. A box extended entirely across the other end of the basin, one side of which was depressed so that the effluent flowed over it in a stream of uniform depth throughout its length. A scum board was attached to this box which prevented the scum from passing out with the effluent. By means of these boxes the flow was distributed across the basin as uniformly as possible. The sewage passed continuously through the tank, except at times when storm water was present to a very noticeable extent.

It was the aim in these experiments to adhere as closely as possible to plain sedimentation, and not to allow complication through septic action. Before the basin showed signs of marked septic action, from 4 to 8 weeks according to the weather, the water was drawn off, and the sludge measured, removed and analyzed.

It was, of course, impossible to stop the periods at exactly corresponding points, and there was more bacterial action at the end of some periods than of others. There was always, however, a decided difference in the appearance of the sedimentation and septic basins, which were side by side. The evolution of gas was less violent, the effluent was lighter colored and there was less odor in the case of the sedimentation tank.

There was very little scum on the sedimentation tank when the periods were terminated. In cold weather, even after a period of 8 weeks, there was more contrast in the appearance of the two tanks than there was in warm weather at the end of a very short time.

The results of these experiments, in relation to the sludge problem, are given in Table IV.

TABLE IV.

Data on Sludge Resulting from Sedimentation.

No.	Duration of Period.	Nominal Rate per Day in Gallons.	Volume of Sludge Pumped from Settling Basin.		Solids in Sludge as Pumped from Settling Basin.	
			Gallons per Million Gallons Sewage Treated.	Relation of Volume Sludge to Volume Sewage.	Per Cent of Solids in Sludge.	Tons of 2 000 Lb. per Million Gallons Sewage.
				Per Cent.		
1	April 5 to May 5, 1902	300 000	1 721	0.17	11.06	0.80
2	May 23 to June 28, 1902	300 000	3 596	0.36	6.18	0.93
3	July 9 to August 2, 1902	½ at 300 000 ½ at 400 000	3 625	0.36	6.43	0.97
4	August 3 to September 1, 1902	400 000	3 581	0.36	4.72	0.70
5	September 6 to October 7, 1902	500 000	3 556	0.36	5.27	0.78
6	October 8 to November 1, 1902	600 000	2 708	0.27	6.65	0.75
7	December 21, 1902, to February 7, 1903	750 000	1 074	0.11	4.16	0.10
8	February 8 to March 20, 1903	750 000	1 559	0.16	7.40	0.48
9	March 21 to May 1, 1903	750 000	860	0.086	7.48	0.27
10	May 3 to May 31, 1903	750 000	1 901	0.19	4.17	0.33
11	June 6 to July 2, 1903	750 000	2 150	0.22	3.15	0.28
12	August 17 to September 12, 1903	1 000 000	1 789	0.18	3.38	0.25
13	September 16 to October 24, 1903	1 000 000	1 439	0.14	3.89	0.23

It will be seen that there is a wide variation in the quantity of sludge produced by sedimentation at the different rates of flow. This is a natural result of varying velocity, but the figures cannot be taken too literally, as the variation in the quality of sewage, and also to a less extent the length of period and temperature, doubtless had a material effect.

During periods 1 and 9 the sewage was largely diluted with surface water. While storm water during actual rain was not allowed to pass through the tank, some street detritus was unavoidably admitted. These facts account both for the smaller volume of sludge and for its greater density during these periods. Leaving out periods 1 and 9, which are obviously abnormal in these two respects, the data in Table V are obtained:

TABLE V. AMOUNT OF SLUDGE RESULTING FROM SEDIMENTATION AT DIFFERENT RATES.

Periods Averaged.	Flow of Sewage per Day in Gallons.	Gallons per Million Gallons Sewage Treated.	Tons Solids per Million Gallons Sewage Treated. Ton, 2 000 Lb.
2 and 3	300 000	3 610	0.95
4, 5 and 6	500 000	3 282	0.74
7, 8, 10 and 11	750 000	1 671	0.30
12 and 13	1 000 000	1 614	0.24

A comparison of the quantity of sludge produced by sedimentation and chemical precipitation is interesting. The volume produced by chemical precipitation in the years following 1901 is materially less than that of former years for reasons given in the discussion of that process. It would seem, however, that the most reasonable comparison between the two methods would be during the years 1902 and 1903, because the sedimentation experiments were conducted during that time. With a flow of 300 000 gal. through the basin daily, the volume of crude sewage sludge amounted to 75 per cent. of the sludge produced by the lime treatment. At a flow of 1 000 000 gal. per day, however, this ratio was reduced to 33 per cent., with the obvious result that a correspondingly greater amount of suspended matter was carried out of the settling tank to the filter beds.

It is important to take into consideration the fact that the flow through the chemical precipitation basins amounted to about 1 000 000 gal. per basin per day.

It is noticeable that the ratio of the weights of solid matter in the sludge produced by sedimentation to that of chemical precipitation is somewhat smaller than the ratio of the volumes produced, the former ranging from 15 per cent. at the high rates to 65 per cent. at the low rates.

There are several things which have perhaps a greater influence upon the weight of solid matter produced than upon the volume of the sludge. Among these are the admission of storm sewage, the addition of lime and the more complete precipitation of iron salts and ordinary suspended matter of the sewage in the case of chemical precipitation.

The sludge from sedimentation resembles that from chemical precipitation in most respects. It is, perhaps, somewhat darker in color, due to the presence of a greater proportion of sulphide of iron. The absence of lime and the flocculent precipitate of ferrous hydrate is quite noticeable. The odors are similar, which fact would tend to show that the crude sewage sludge had not become thoroughly septic.

This sludge was conveniently disposed of by filter pressing. The cost was about one third in excess of the cost of pressing a corresponding volume of sludge from chemical precipitation, due largely to the increased amount of lime required. The amount of lime used was about 100 lb. per 1 000 gal. pressed.

The fact that sludge partitions were placed in the sedimentation basin made it possible to compare the quantity and quality of the sludge deposited in the four sections, the data for which are presented in Table VI.

The depth of sludge deposited at the different rates of flow were nearly the same, averaging from 8 to 9 in. at all rates. As would naturally follow, the distribution varied with the flow, the greater the velocity the further the sludge was carried; so that with the smallest flow the depth in the first section was greatest, and least in the fourth section.

It is interesting to note that the ratio of volatile matter to the total residue on evaporation, about 2:3, was nearly uniform in all sections and at all rates.

In comparing the amount of nitrogenous organic matter, it will be noticed that the proportion of organic nitrogen decreases from section to section. On the other hand, it increases in all the sections with the velocity. The large proportion of nitrogen in the first section at the 1 000 000 gal. rate may perhaps be accounted for by the separation of the coarser matter, which formed scum, from the finer particles which made up the sludge.

TABLE VI.

A Comparison of the Sludge Deposited in the Different Sections of the Sedimentation Basin at Different Rates of Flow.

Flow through Basin.	Residue on Evaporation. (Per Cent.) Total. Sections. 1	2	3	4	Volatile. Sections. 1	2	3	4	Fixed. Sections. 1	2	3	4	Proportion of Volatile to Total Residue (Per Cent.). Sections. 1	2	3	4
500 000 gal.	5.93	5.72	3.98	2.50	3.71	3.62	2.88	1.54	2.22	2.10	1.10	0.96	62.56	63.28	72.36	61.60
750 000 ,,	5.84	4.86	3.35	2.85	3.69	3.13	2.18	1.79	2.15	1.74	1.17	1.06	63.19	65.64	65.09	62.82
1 000 000 ,,	4.90	3.52	2.83	2.40	3.11	2.28	1.89	1.58	1.79	1.24	0.94	0.82	63.48	64.77	66.79	65.85

Flow through Basin.	Organic Nitrogen in Wet Sludge (Per Cent.). Sections. 1	2	3	4	Organic Nitrogen in Dried Sludge (Calculated) (Per Cent.). Sections. 1	2	3	4	Depth of Sludge (Inches). Sections. 1	2	3	4
500 000 gal.	.214	.194	.067	.047	3.61	3.39	1.68	1.88	17	8	5	3
750 000 ,,	.280	.259	.178	.133	4.80	5.33	5.31	4.66	16	10	7	4
1 000 000 ,,	.667	.338	.160	.212	13.61	9.60	5.65	8.81	15	9	5	6

In this case the scum over section 1 was 12 in. thick, while in the periods run at lower rates there was much less scum formed. This coarser matter consisted largely of paper, cloth and grease, in which the nitrogen was comparatively low, and when this matter was separated from the sludge the nitrogen content of the latter was proportionally increased.

Sludge and Scum Resulting from Septic Treatment.

The following experiments with the septic treatment of sewage were started in July, 1901, and continued until July, 1903. The first experiment began July 8, 1901, and was terminated March 1, 1902, when the tank was entirely cleaned out. The second series of experiments began May 22, 1902, and was terminated July 2, 1903. The settling basin used for these studies has already been described under the subject of sedimentation, except that during the first experiment there were no sludge partitions nor scum boards in the basin. The principal points of importance are given in Table VII.

TABLE VII. Statistics Regarding the Sludge Produced by the Septic Tank.

	Experiment No. 1. July 8, 1901, to March 1, 1902. Gallons.	Experiment No. 2. May 22, 1902, to July 2, 1903. Gallons.
Contents of basin	350 000	350 000
Rate of flow through basin.	300 000 to 500 000	300 000 to 750 000
Total flow for period......	99 790 000	185 000 000
Sludge remaining at end of period	79 000	56 250
Sludge remaining at end of period, per million gallons sewage.................	792	304
Relation of volume of sludge to sewage..............	0.079 per cent.	0.030 per cent.
Solids in sludge...........	4.40 per cent.	14% { 5.55% sludge; 28.84% scum
Solids in sludge per million gallons sewage..........	0.145 tons	0.177 tons

The results of these two experiments were in general quite similar. The most notable difference between them was that in the first experiment there was practically no scum formed. There was occasionally a small amount of floating matter on the surface of the basin, but this was frequently disturbed by wind or rain and driven to the bottom of the tank. There was nothing which could be called permanent scum.

It is also important to note that the sludge formed during the second experiment was denser than that formed during the first, and when the scum is added this difference becomes very material. The amount of solid matter in the sludge at the end of the second experiment was greater per million gallons sewage than at the end of the first. These variations are, however, probably due to the fact that during the second run the settling basin was provided with sludge partitions and scum boards.

When sewage is first turned into the septic tank a considerable proportion of the suspended matter settles to the bottom. The bacterial life is greatly intensified in the sludge, as shown by the number of bacteria found, the sludge frequently containing as many as 12 000 000 bacteria per cu. cm., while the effluent from the tank rarely contained more than 1 000 000. The action of the germs on the organic matter of the sludge produces large quantities of gas. This gas is held mechanically by the solid matter until it is collected in sufficient quantity to lift large amounts of the sludge. At such times there is a violent ebullition, which carries a great deal of suspended matter from the bottom to the top of the tank.

Sewage contains a very considerable amount of fats. Determinations made at the time of these experiments disclosed as much as 9.58 per cent. by weight in the dry residue on evaporation.

Soon after the septic tank is put into operation, if the weather is warm, a thin film of oil is noticeable on the surface of the water. The sludge which is brought to the top of the basin by the gases entangled in it is surrounded with a film of grease, which assists in retaining it at the surface. The film of oil also prevents the free liberation of the gas from the water, so that there soon forms a thin coating of sludge and grease containing much gas which has been liberated from the sludge. If a severe wind storm or rain should take place under these conditions this thin film of scum would be broken up, the gas liberated and the solid matter driven to the bottom of the basin, and this may account for the frequent failure, under certain conditions, of the septic process to produce scum.

During cold weather the grease upon the surface is congealed, so that there is no film of oil on the surface to assist in the formation of a scum.

If the light scum described is undisturbed by the elements, frequent additions of gas and solids cause it to become thicker from time to time, until it acquires sufficient stability and

tenacity to act as a mass. In this condition it contains a very large quantity of gas, which makes the crust acting as a unit much lighter than water; hence it floats, like a rubber sponge, on the surface of the sewage, the upper portion rising considerably, often 6 in. above the water. As the mass gradually rises, the surface is dried by the action of the sun and wind, and becomes tough and strong, a condition not as likely to obtain in a covered tank. With the formation of the tough surface, birds and small animals can walk upon it, and after the scum has acquired a considerable thickness a man can stand with safety upon it, as illustrated by the accompanying photograph.

An effort was made, after the scum had attained a thickness of at least 12 in., to disengage the gas from it, so that it might settle to the bottom of the basin. This effort, however, was unsuccessful, as there was such a large quantity of gas that all of it could not be disengaged, and the liberation of gas from the sludge was so rapid that that which was expelled from the scum was immediately replaced by a fresh supply from below. Table VIII gives some interesting statistics regarding the thin and thick scum and the sludge.

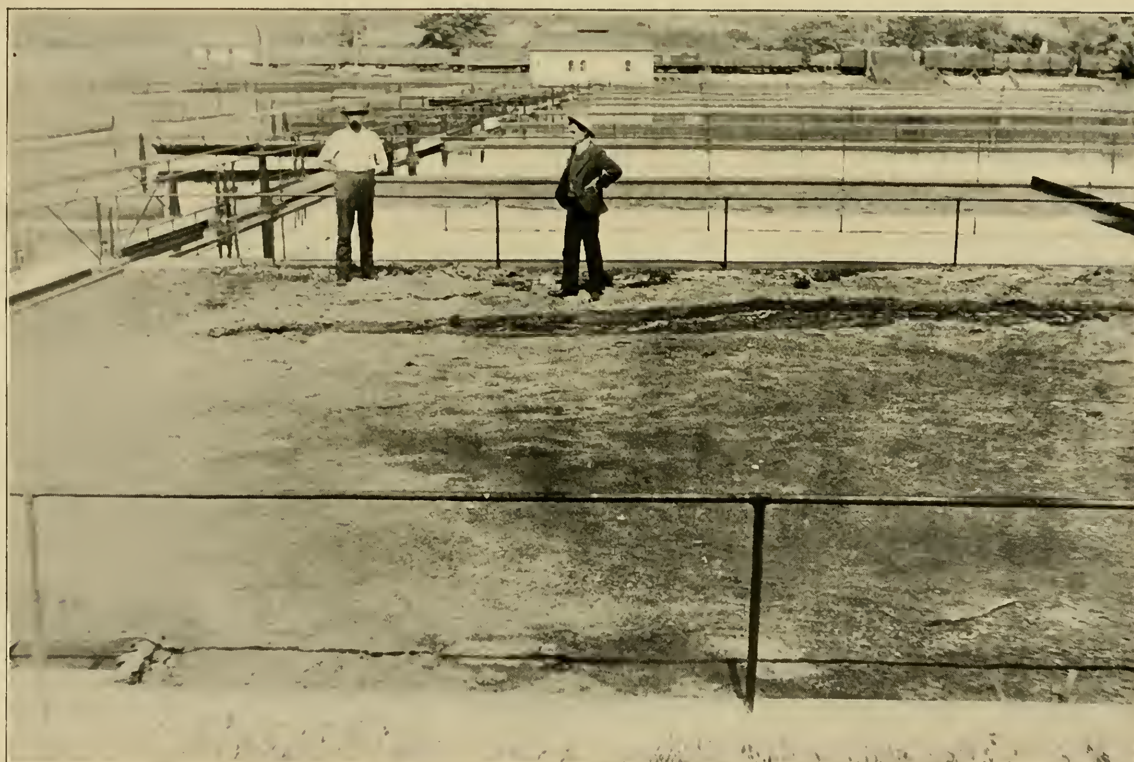
TABLE VIII. Composition of the Sludge and Scum of the Septic Tank.

	Fats in Dry Sample. Per Cent.	Fats in Wet Sample. Per Cent.	Organic Nitrogen. Per Cent.		Total Solids. Per Cent.	Volatile Solids. Per Cent.	Fixed Solids. Per Cent.	Specific Gravity.
			Wet Sample.	Dried Sample.				
Thin scum...	11.83	0.81	.280	4.076	6.87	3.79	3.08	1.021
Thick scum.	10.24	2.95	.909	3.152	28.84	15.30	13.54	1.062
Sludge.... .	5.83	0.32	.273	4.919	5.55	2.35	3.20	1.040

Specific gravity determined by weighing measured volume of liquid scum or sludge. Gas was completely expelled by stirring.

The sludge from the septic tank was black in color, very finely divided, slimy and always of an extremely offensive odor. The scum, however, served a useful purpose in the basin by preventing the escape of the offensive odors into the surrounding air, and by protecting the sewage from severely cold weather. Both the sludge and the scum varied from time to time in amount, and it was somewhat difficult to explain just the reason for this.

Sludge decomposes more rapidly during warm weather,



Scum on Septic Tank. The Men are Standing on the Scum.

and consequently there was a general tendency to form a thicker crust at such times, and, conversely, during the winter season the sludge tended to increase in quantity. There were frequent changes in the depth of scum and sludge. apparently coinciding with each other, which indicated that at times a large body of sludge was carried up and formed a part of the crust, and later gases were liberated, so that corresponding amounts of scum were deposited, increasing the amount of sludge. These changes were, however, difficult to study, and no other explanation could be given than the entangling of the gases, and later the liberating of the same.

The action of the gases seemed to separate the sludge into classes, the coarse material, such as paper and cloth, being carried to and retained in the scum, the resulting sludge consisting of very finely divided matter. This separation was also affected by both the sludge partitions and the scum boards.

It is suggested, by the several conditions existing in these two experiments, that the presence of a large quantity of coarse particles may be an important factor in the formation of a permanent and increasing scum.

The absence of the grosser matters in well-screened sewage may account for the non-appearance of scum in some septic tanks. It was observed that in the sludge resulting from the first experiment there was very little coarse material, probably due to disintegration by septic action. In the second experiment, however, the coarse matters in the scum did not appear to have been acted upon to any great extent. These two facts would tend to show that the septic action is very largely confined to the sludge.

At the close of the second experiment the crust in the first section was 18 in. deep and very coarse; in the second section it was barely 6 in. deep and comparatively fine; while in the third and fourth sections there was a mere film of oil with a small amount of solid matter with it. This shows that the scum board retained the grosser solids in the first section.

Table IX is a statement of the solids found in the sludge and scum of the different sections of the basin. The solids in the scum of the second section, however, are calculated from the analyses of the thin scum, and are undoubtedly less in quantity than actually existed.

It is interesting to note the decrease in the proportion of volatile matter to total solids from the first section where the sewage entered the basin to the fourth section from which it

TABLE IX.— SOLIDS IN SLUDGE IN THE DIFFERENT SECTIONS OF THE SEPTIC TANK.

(PER CENT.)

No. of Section.	Depth of Sludge. Inches.		Total Solids.	Volatile Solids.	Fixed Solids.	Relation of Volatile to Total Solids.
	Scum	Sludge.	(Inc. Scum)	(Inc. Scum)	(Inc. Scum)	(Inc. Scum)
1	18	6	2.58 (22.28)	1.30 (11.80)	1.28 (10.48)	50.38 (52.97)
2	6	10	4.95 (5.53)	2.30 (2.75)	2.65 (2.78)	46.46 (49.73)
3	Film	9	6.62	2.81	3.81	42.42 ....
4	Film	12	6.86	2.62	4.24	38.19 ....

Number of Section.	Organic Nitrogen in Wet Sludge.		Organic Nitrogen in Dried Sludge.	
		(Inc. Scum)		(Inc. Scum)
1	0.037	(0.691)	1.43	(3.10)
1	0.144	(0.265)	2.91	(4.79)
2	0.370	....	5.59	....
3	0.290	....	4.23	....

was discharged. Considering the sludge alone, however, the organic nitrogen increases from section to section.

There was more nitrogen in the scum of the first two sections than there was in the corresponding sludge. Combining sludge and scum of these sections, the amount of nitrogen was found to be fairly uniformly distributed throughout the four compartments of the basin.

The distribution and amount of nitrogen were quite different from that found in the experiments upon sedimentation. There was more nitrogen present than when the sedimentation tank was run at the 500 000 gal. rates, and considerably less than at the rate of 1 000 000 gal.

The greatest proportion of nitrogen was found in the second and third section, which was also true with the 750 000 gal. rate in the sedimentation tank, while at the 500 000 gal. and 1 000 000 gal. rates the first and second sections contained sludge which was much richer in nitrogen.

Septic action was so vigorous in the first section of the septic tank that large quantities of gas were evolved. This gas contained a substantial amount of nitrogen, which fact

undoubtedly accounts in part for the smaller proportion of nitrogen found in the sludge and scum of this compartment. It is possible also that the increase in free ammonia in the effluent may offer another explanation of this condition.

The province of the septic tank is to control and, in part at least, to destroy and dissolve some of the suspended substances in sewage so that subsequent processes of oxidation may not be impeded by them.

The extent to which this purpose is realized and the efficiency as compared with chemical precipitation, sedimentation or no preliminary treatment at all, is shown by the following tabulation of the volume of sludge and weight of solid matter in the sludge and effluent.

Volume of Sludge Produced by Chemical Precipitation, Sedimentation and Septic Tank.

(Gallons per 1 000 000 Sewage.)

Chemical precipitation (average 1902 and 1903)......	4 872
Sedimentation (average at all rates)................	2 544
Septic tank (average of two experiments)...........	548

Suspended Solids in Effluent and Sludge from Chemical Precipitation, Sedimentation and Septic Tank.

(Tons [2 000 lb.] Dry Solid Matter per 1 000 000 Gallons Sewage.)

	Effluent.	* Sludge.	Total.
Sewage (from outfall sewer: average 1902 and 1903)...........................	1.247	....	1.247
Chemical precipitation (average 1902 and 1903)................................	0.250	1.435	1.735
Sedimentation (average at all rates).......	0.601	0.580	1.181
Septic tank (average of two experiments)	0.840	0.161	1.001

* Including scum.

The volume of sludge produced by chemical precipitation may be varied greatly by manipulation affecting its density. It would probably be impracticable, however, under existing conditions in Worcester, to reduce the volume materially below that here given. This amount, however, is the largest appearing in the table.

Sludge from sedimentation comes next in quantity, being about 52.2 per cent. of the volume produced by chemical precipi tation. As the only difference between sedimentation and the

septic process lies in the fact that the sludge is removed from the sedimentation tank at frequent intervals, it is apparent that the amount of sludge can be varied at will until it reaches a volume corresponding to that produced by the septic tank. In these experiments an effort was made to remove it before the fermentation had become very active.

Less sludge is produced by the septic tank than by either of the other methods. In these experiments it amounted to 11.2 per cent. of that produced by chemical precipitation during 1902 and 1903.

The weight of suspended solids in the sludge and effluent from chemical precipitation is found to be materially in excess of the amount present in the crude sewage. This is due to the addition of lime, a large portion of which remains undissolved, and the precipitation of hydrate of iron. In the sewage the iron compounds are largely in solution, so that their precipitation transforms them from soluble to insoluble matter.

The suspended matter accounted for in the sedimentation process is remarkable, being within about 5 per cent. of that in the original sewage — probably within the limits of error in measuring and sampling.

The septic process shows the lowest weight of solid suspended matter, as it did the smallest volume of sludge. The reduction as compared with crude sewage amounts to about 20 per cent.

In considering this reduction, the fact should be borne in mind that much of the soluble iron of the sewage is precipitated in the septic tank, thereby increasing the suspended matter above that originally in the sewage. It would appear, therefore, that the actual reduction of organic matter must have been in excess of 20 per cent. by an amount equivalent to the weight of iron sulphide precipitated.

Suspended Solids in the Effluent from Chemical Precipitation and the Effect of the Same upon Intermittent Filtration.

The amount of suspended solids in the effluent from chemical precipitation varies from a trace under the best conditions to about 10 parts per 100 000, or 833 lb. per 1 000 000 gal. Of this amount, roughly, one half is organic and volatile.

It has been the custom in the filtration of chemical effluent to apply that of poorest quality to the beds, and although no

Filter Beds, Worcester, Mass.

Removing Clogging Material from Filter which has Received Effluent from Chemical Treatment, Worcester, Mass.

complete record has been kept of the suspended solids in the water applied, it may be estimated from various determinations to be about 500 lb. per 1 000 000 gal.

This suspended matter is in a finely divided condition and readily penetrates the sand to a depth of nearly 2 in. As this process continues the pores of the sand gradually fill with sludge, and on application of the effluent the mass quickly becomes saturated with water, retards the progress of filtration and dries out very slowly, the sand below this stratum draining rapidly. The gradual change in the nature of the surface layer decreases the capacity of the filter, until it becomes imperative to remove the material causing surface clogging.

It has been found, however, that in winter freezing makes this stratum more porous, so that a larger quantity of water will pass through it than during warmer weather. This fact is well illustrated by the record of water filtered through one bed, as follows:

	Gallons.
June, 1903	1 473 000 (two days)
July, 1903	10 943 000
August, 1903	9 110 000
September, 1903	4 963 000
October, 1903	3 154 000
November, 1903	1 895 000
December, 1903	4 026 000
January, 1904	5 944 000
February, 1904	6 248 000
March, 1904	5 926 000
April, 1904	2 470 000
May, 1904	2 922 000

This record was made by one of four 1-acre filter beds, which were thoroughly scraped to a depth of about 4 in. in June, 1903, and the effluent from chemical precipitation applied for one year. At the end of this time about 1.5 in. of poor material had accumulated on the surface of the beds, and they were working very slowly. Temporary relief could have been obtained by harrowing, but experience has shown that it is not wise to mix the poor material with the clean sand.

On two previous occasions about one quarter (in depth) of the clogged sand had been removed from some beds, others being allowed to rest a few weeks during the cleaning. It was found that the partial removal accomplished little more than resting. Accordingly, in June, 1904, practically all of the poor material was removed. The dividing line between the poor

material and the comparatively clean sand was fairly well defined.

The total amount of chemical effluent applied per acre to the 4 beds for the period of 336 days was 58.44 million gal., or at an average rate of 174 000 gallons per acre daily.

The material removed from these 4 beds in June, 1904, amounted to 1.4 in. in depth and measured 208 cu. yd. in the cars as hauled away. This amount is equivalent to 3.56 cu. yd. per 1 000 000 gal. of chemical effluent filtered during the period.

The cost of cleaning these beds and removing the waste material was \$95.03 per acre, or \$0.45¾ per cu. yd., equivalent to \$1.62½ per 1 000 000 gal. filtered.

The material removed from the filters was analyzed with the following results:

	Per Cent.
Moisture	13.92
(Sample dried at 110 degrees cent.)	
Ferric oxide	3.48
Calcium oxide	1.00
Organic nitrogen	0.263
Sand	85.00
Organic matter (by ignition)	5.58

At times sufficient lime was precipitated on the surface of the filter to form a hard crust which impeded the passage of water. This crust was very thin, not exceeding one quarter of an inch in thickness. It was broken up by scratching with a horse wire-tooth weeder, after which the water penetrated the sand without difficulty from this source.

Suspended Solids in the Effluent from Plain Sedimentation and the Effect of the Same upon Intermittent Filtration.

The amount of suspended solids in the effluent from plain sedimentation depends upon the strength of the sewage, and consequently upon the rainfall and season of the year, as well as upon the rate of flow through the basin. This fact should be borne in mind in the examination of Table X. The amount is much in excess of the suspended solids in the effluent from chemical precipitation, but considerably less than in the septic effluent. This subject is further treated in connection with the discussion of the suspended solids in the effluent from the septic tank.

The action of the suspended solids in the effluent from plain sedimentation in clogging the surface of filters is similar

to that previously described in connection with the filtration of chemical effluent, except that a greater proportion remains on the surface. It is, however, impossible to remove this without removing at the same time a large amount of sand. This cleaning does not remove the foreign matter entirely, as a portion of it has penetrated the filter to a depth of from 1 to 2 in. and in time it will be necessary to remove this portion also.

The only explanation of the difference in the effect on the filters of the suspended matter from the various processes of preliminary treatment seems to lie in the physical condition of that matter. It is very noticeable that in the effluent from sedimentation the solids, although finely divided, are of a somewhat fibrous nature. The fibers interweave and form a sort of mat or fabric. As soon as this begins to build it retains a large proportion of the fine material, some of which is granular, and would penetrate the filter were it not retained on the fibrous film. More fiber builds on to the mat with each application of settled sewage until the accumulation becomes so thick that it will not allow the water to pass readily through it. It is then found that, after drying, this surface layer can be raked off without taking as large a proportion of sand as when the surface of a bed which has received chemical effluent is scraped.

In a well-settled sewage, however, there is not enough fiber to prevent the fine material from entering the pores of the filter to such an extent that the upper layer of sand must be taken off at intervals.

TABLE X. Suspended Solids in the Effluent from Sedimentation.

Date of Period.	Nominal Rate per Day for Period in Gallons.	Suspended Solids in Pounds per Million Gallons.		
		Total.	Volatile.	Fixed.
April 5 to May 5, 1902	300 000	916	233	683
May 23 to June 28, 1902	300 000	1 525	858	667
July 9 to Aug. 2, 1902	½ at 300 000 ½ at 400 000	1 191	616	575
Aug. 3 to Sept. 1, 1902	400 000	1 417	575	842
Sept. 6 to Oct. 7, 1902	500 000	1 775	617	1 158
Oct. 8 to Nov. 1, 1902	600 000	1 333	800	533
Dec. 21, 1902, to Feb. 7, 1903,	750 000	692	275	417
Feb. 8 to March 20, 1903	750 000	1 191	558	633
March 21 to May 1, 1903	750 000	841	433	408
May 3 to May 31, 1903	750 000	1 016	608	408
June 6 to July 2, 1903	750 000	1 042	567	475
Aug. 17 to Sept. 12, 1903	1 000 000	1 616	933	683
Sept. 16 to Oct. 14, 1903	1 000 000	1 358	625	733

With crude, unsettled sewage there will be formed a much heavier coating upon the surface of the filter, and this will doubtless retain much more of the fine particles, so that it will be necessary to remove the upper portion of the sand only at comparatively long intervals.

Suspended Solids in Sewage and the Effect of the Same upon Intermittent Filtration.

During the year 1905, crude sewage direct from grit chambers was filtered upon several sand beds. The filters were flowed only during the day, and therefore the sewage was much stronger than the average of that received during the 24 hr. The amount of suspended matter in this sewage ranged from 2 000 lb. to 4 000 lb. per million gal., averaging for the year 3 500 lb., of which about two thirds was organic and volatile. The amount filtered per acre per day averaged 91 000 gal.

It was noticeable that the suspended matter in the sewage passing from the grit chambers was much coarser than that in the effluent from the sedimentation tank.

The coarse and fibrous material is retained on the surface of the sand, forming a woven mat. As soon as this mat begins to form, which is as soon as the first dose is applied, it retains the suspended matter in the sewage subsequently turned on to the filter. In this way the mat continually increases in thickness.

After the water has passed through, this material dries, weather conditions permitting, shrinks, cracks and usually curls, separating from the sand. While the suspended matter undoubtedly reaches the sand to a limited extent through the cracks in the mat, in the main the mat forms a very complete protection.

The large quantity of suspended matter in the unsettled sewage makes it necessary to clean the beds more frequently than in the case of settled sewage. It has been found necessary to rake over portions of the beds at least as often as once in 2 weeks. This material is generally raked up into piles and removed from the beds only after it has accumulated to quite an extent. Great care is taken to prevent the mixing of any of this material with the sand, and it is interesting to note how clean and soft the sand immediately under the mat remains.

The clogging material on these beds has been removed under several different conditions. When the thermometer registers about 32 degrees fahr., this material freezes in the form of a crust

Mat Formed on Filter which has Received Crude Unsettled Sewage, Worcester, Mass.

Surface of Filter which has Received Crude Unsettled Sewage, Worcester, Mass.

Leveling Bed after Removing Deposit.

and can be taken off with very little labor. When taken off in this way considerable sand adheres to the bottom of the crust and is removed from the filter. If the weather is extremely cold, it is impracticable to remove the crust, as it comes off in thick pieces, sometimes 2 or 3 in. in thickness, all but the upper quarter of an inch being clean sand.

The quantity of refuse removed from the surface of these filters has amounted to about 14 cu. yd. per million gal. of sewage treated, and the cost of removing the same averaged $0.49 per cu. yd.

The two views illustrate clearly the description just given. The strength and size of the mat of fibrous material is well illustrated by the large piece which is being held up by the four men, and the other illustrates how this mat can be rolled up and taken off without disturbing the underlying sand.

The following analysis of this leather-like substance is interesting:

	Per Cent.
Moisture	6.13
Loss on ignition	51.45
Organic nitrogen	2.31

It is very noticeable that the coarsest material settles nearest to the distributor; therefore, as would be expected, less sand is removed from this portion of the bed at each cleaning than from the center of the bed. This is well illustrated by the analyses given in the following table.

ANALYSES OF REFUSE MATERIAL REMOVED FROM BEDS 19 AND 23, NEAR AND REMOTE FROM DISTRIBUTORS.

	Bed 19.		Bed 23.	
	Near Distributor.	Remote from Distributor.	Near Distributor.	Remote from Distributor.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Moisture	14.44	12.53	28.0	1.10
Dry solids	85.56	87.47	72.0	98.90
		Dried at 110° cent.		
Loss on ignition	11.29	6.76	16.16	9.87
Fixed solids	88.71	93.24	83.84	90.13
*Insoluble fixed solids	72.86	87.55	76.71	85.32
Ferric oxide	(Not determined)		0.027	0.023
Organic nitrogen	0.520	0.377	0.918	0.827
Weight per cu. ft.	63.26 lb.	81.85 lb.	70.69 lb.	82.36 lb.
Specific gravity (of mass)	1.001	1.31	1.13	1.318

* This determination approximates the amount of sand removed from the filter; but includes, of course, that portion of the fixed suspended matter of the sewage which is insoluble in hydrochloric acid.

The difference between the analyses given in this table and that immediately preceding is due to the fact that the latter analyses are of the average of the material removed, which is quite different from the leather-like mat which is represented by the first set of analyses.

Suspended Solids in the Effluent from the Septic Tank and the Effect of the Same upon Intermittent Filtration.

The septic tank received sewage continuously from May 23, 1902, until July 2, 1903, except when storm water was running, and except from November 1 to December 21, 1902, when the basin was shut down on account of the construction of a new effluent channel. The basin was next to another tank of exactly the same dimensions, and which was used for sedimentation. To assure uniform conditions in the two tanks, they were operated at the same rates during the same periods of time. The duration of each period was fixed by the conditions existing in the sedimentation tank, which was shut off before marked septic action was apparent. To make the results of the septic treatment and sedimentation strictly comparable, the samples from the septic tank were taken through periods which corresponded with those of the settling basin.

From the results given in Table XI, it is difficult to trace any very decided condition to the rate of flow through the basin. It was believed, however, from the practical working of

TABLE XI. Suspended Solids in the Effluent from the Septic Tank.

Period.	Nominal Rate of Flow per Day.	Suspended Solids in Pounds per Million Gallons.		
		Total.	Volatile.	Fixed.
May 23 to June 28, 1902	300 000	1 708	1 008	700
July 9 to Aug. 2, 1902	½ at 300 000 ½ at 400 000	1 300	442	858
Aug. 3 to Sept. 1, 1902	400 000	1 734	775	959
Sept. 6 to Oct. 7, 1902	500 000	2 816	1 275	1 541
Oct. 8 to Nov. 1, 1902	600 000	1 942	1 000	942
Dec. 21, 1902, to Feb. 7, 1903,	750 000	922	367	555
Feb. 8 to March 20, 1903	750 000	1 650	817	833
March 21 to May 1, 1903	750 000	1 291	683	608
May 3 to May 31, 1903	750 000	1 700	1 058	642
June 6 to July 2, 1903	750 000	1 734	1 116	618
Average		1 680	854	826
Average of sedimentation for same period..		1 202	591	611

the tank and filter beds which received the septic effluent, that 750 000 gal. was as high a rate as could be passed through the basin without carrying out an unreasonable amount of suspended matter.

There is a noticeable difference in the amount of solid matter carried out of the basin between the warm and cold periods. The 750 000 gal. rate for 5 periods produced less suspended matter in the effluent than was present in several warm periods at much lower rates of flow. It is quite probable, however, that the small amount of suspended matter in the first 750 000 gal. period was due to the fact that the tank was shut off and standing full for about 6 weeks immediately preceding this period.

The high solids during the September period were apparently due to the very active condition of the tank, which condition has been found to be usual during the months of August and September. These two months have always constituted a period of very active fermentation in the chemical sludge as well as in the septic sludge.

The most important fact disclosed in a comparison of the suspended solids in the effluents from septic treatment and sedimentation is that they were, in every period, higher in the effluent from the septic tank. This was doubtless due to the active fermentation going on in the septic tank, which condition was not allowed to exist in the sedimentation basin. Even the 1 000 000 gal. rate during August and September in the sedimentation basin was productive of lower suspended solids in the effluent than the average of all the periods of the septic tank.

The suspended solids in the septic effluent from July 8, 1901, to March 1, 1902, averaged about 100 lb. per 1 000 000 gal. higher than the average during the second experiment. This was undoubtedly due to the scum boards and sludge partitions which were not constructed until after the conclusion of the first experiment.

The suspended matter in the effluent was very finely divided, and contained considerable sulphide of iron. When applied to filters, the solids penetrated the sand and clogged the pores much as do the solids in the chemical effluent. There was not a great difference between the results of filtering the effluents from septic treatment and sedimentation. The odor from the filter receiving septic effluent was very much more offensive than that from the filter receiving settled sewage.

Summary of Conclusions.

In drawing conclusions from the foregoing description of various methods of sewage treatment, due consideration should always be given to the fact that the sewage of Worcester contains large quantities of manufactural wastes, the most important being that from the foundries and wire mills, consisting largely of sulphate of iron.

Following are a few of the conclusions which might reasonably be drawn from the facts already presented:

Chemical Precipitation — Sludge.

1. Sludge from chemical precipitation is more voluminous and of greater net weight than that from sedimentation or the septic tank.

2. Where waste pickling liquids from foundries and wire mills are discharged into the sewers, a large volume of sludge is produced by the addition of lime, thus precipitating the iron.

3. If storm water is admitted to the sewers large quantities of road detritus will be deposited in settling basins or grit chambers, and the proportion of mineral to organic matter will be correspondingly increased.

4. Sludge from chemical precipitation decomposes with the evolution of gas in much the same way as in the case of the septic tank.

Sludge Pressing.

5. Sludge is most expeditiously pressed when it has reached a density of from 4 to 7 per cent. solids and is comparatively fresh.

6. Fresh sludge requires from 20 to 30 lb. of lime per 1 000 gal. to assure economical pressing, and if decomposition has made considerable progress, as much as 100 lb. may be needed.

7. Septic tank sludge containing large quantities of sulphide of iron is extremely difficult to press.

8. Sludge removed in a fairly fresh state from the sedimentation basin is readily pressed with 100 lb. of lime per 1 000 gal.

Sedimentation — Sludge.

9. The volume and the weight of solids of sludge vary inversely with the flow through the settling basin.

10. The quantity (both by volume and by weight of solids) of sludge produced is always less than that resulting from chemical precipitation.

Septic Tank — Sludge.

11. The sludge always had a very offensive odor, possibly due to sulphur compounds, although hydrogen sulphide was never found to be present in the gas evolved from the tank.

12. Septic action was far more vigorous in the sludge than in the scum, there being comparatively little disintegration of the latter.

13. If the formation of scum can be prevented, there will be a disintegration of the coarser particles at least into finer matter.

Suspended Matter in Effluent from Chemical Precipitation.

14. Enough suspended matter passes out of settling basins with effluent to cause clogging of sand filters.

15. This material must be removed from surface of filters at intervals, but as it is finely divided it is impossible to scrape it off without taking also a very large proportion of sand.

16. Lime in effluent (in suspension and solution) is precipitated on and near surface of sand, forming a hard but thin crust, causing clogging.

This crust may be easily broken up by mechanical means.

Suspended Matter in Effluent from Sedimentation.

17. Two or three times as much solid matter escapes with the effluent as in the case of chemical precipitation.

18. Some of the solid particles appear to be of a fibrous nature and gradually form a fabric on the surface of the filter.

19. If the sedimentation process is efficient, the suspended matter will be so fine that it will penetrate the sand, soon necessitating its removal to a substantial depth.

Suspended Solids in Sewage.

20. The coarse, fibrous substances form a mat on the surface of the filter. This mat is strong and forms a very good protection to the surface of the sand against finely divided particles entering the pores of the sand.

21. The surface of the filter requires frequent cleaning. Clogging material should not be removed when very wet or when frozen to the sand below.

Suspended Solids in Septic Tank Effluent.

22. A flow equivalent in 24 hr. to about twice the capacity of the tank is as much as should be run through it unless special

provision is made for settling out the suspended matter before admitting effluent to filter.

23. The amount of suspended matter in the effluent is considerably greater than in that from sedimentation or chemical precipitation.

24. The suspended solids do not necessarily vary in amount directly or indirectly with the flow through the basin, as temperature conditions have a marked effect on account of increasing or decreasing fermentation.

25. The suspended matter was very finely divided and consisted largely of sulphide of iron.

26. The surface of the sand filters became clogged with these substances in a short time.

27. Very offensive odors were given off from filters when flooded and when wet.

DISCUSSION.

Mr. R. S. Weston. — This paper needs no commendation. It certainly puts the subject in a very clear light.

The relation of the suspended matter in sewage to the problem of sewage disposal is a very important question, especially that phase of it which concerns the physical character of the suspended matter. During the past few years experts have viewed the problem from two entirely different standpoints. At one time it was believed that if the sludge could be precipitated a great gain was effected, while more recently it has been held that if the sludge could be decomposed in a septic tank and thereby lessened in volume, a greater gain was being made; but now it is being learned that the physical character of the suspended matter is fully as important a factor as the apparent amount precipitated and left for subsequent disposal. This is on account of the fact that what really seems to be in solution is not necessarily permanently in solution. For example, it is well known that if one allows a sample of sewage to settle until it is clear, or removes the apparent suspended matter by filtration, some of the organic matter in the clarified sample will subsequently become insoluble and precipitate. In other words, what appears to be soluble precipitates. Matter in this form is called colloidal, and in this state exists neither as true dissolved matter nor suspended matter, but as matter which is in semi-solution. In a septic tank effluent, as Mr. Eddy has shown, there is more of this colloidal or semi-soluble matter than in fresh settled sewage. The experience of the writers of this

paper goes to show that filters receiving sewage clog more rapidly where there are the largest percentages of colloidal matter.

Mr. George A. Carpenter. — *Mr. Chairman and Gentlemen:* I regret very much indeed my inability to put together some of the data which I have gathered in my use of intermittent filtration during the last ten years, and get this information into such shape as would be presentable before this society. I have quite a mass of data, and some of it I have not yet had time to analyze even for my own benefit, let alone the getting of it into shape to present before a meeting like this. I have been much interested in the paper presented and in the review of the advance sheets that were sent to me. I have tried hard to find exceptions to some of the facts stated by Mr. Eddy and Mr. Fales, but have really been unable to do so, for my own experience coincides very uniformly with theirs in respect to the use of the septic tank, the effluent from the same and from sedimentation. I have had no actual experience with chemical precipitation methods. In one respect I am inclined to differ a little from Mr. Eddy, my own experience pointing to the desirability of getting out all of the organic matter as soon as possible before turning the sewage on to the sand filters. I agree with Mr. Eddy that organic matter turned on to the sand will form a mat which will clog the surface and will serve to gather the more finely divided matter, helping to keep it from entering the pores of the sand. That is a satisfactory method in summer, in warm weather, when it will dry out. But my own experience would indicate that the same mat forming in cold weather, clogging the sand and preventing the sewage from getting through, will, under such conditions, render the whole mass liable to become frozen, and will throw the whole bed out of commission. If you attempt to take it off at that time, provided you can, the result is, as Mr. Eddy has stated, that it pulls up two or three inches of sand with it. And so my later practice at Pawtucket has been, through the winter months, to first send the sewage through a small grit chamber, where the flow is greatly reduced, and through a rack, taking out all the suspended matter possible. We have found that we are able to collect in that small grit chamber, on the average, 1 000 lb. of dry solid matter per million gallons of sewage flowing through. It is taken from the chamber in carts and dumped into a hole in the ground, with the result that a large percentage of the water drains away, and the sludge can be covered with sand and the hole filled up. No offense is caused in the winter if this is done.

There are a number of points that I wish I were able to take up and discuss, giving the data that I have gathered in my own experience, but I am not prepared to do so in a proper manner to-night. Recently we have had a troublesome but interesting problem with our filter beds, which have now been running some ten years. The trouble has apparently been caused by a filling of the pores of the sand to a considerable depth with organic matter. This might have been occasioned by an increase in the strength of the sewage, which, in our case, will run about two parts of albuminoid ammonia per 100 000 parts, by a reduction of the time allowed the sewage in passing through the settling tanks, or by forcing of the beds by the application of more sewage than ought to have been applied. I might state, in passing, that the experience in Pawtucket is that it does not seem advisable to dose the beds at an average rate exceeding 50 000 or 60 000 gal. per acre per day, for 365 days in the year. The dose applied, however, is at the rate of 100 000 gal. per acre, and the beds are dosed in rotation, but not every day for 365 days in the year.

Interesting investigations have recently been undertaken to ascertain the amount of organic matter, as indicated by the albuminoid ammonia, which had accumulated in the sand. These showed from 35 to 95 parts per 100 000 albuminoid ammonia in the upper three inches, from 26 to 44 parts per 100 000 in the second three inches, from 12 to 21 parts per 100 000 in the second six inches, from 5 to 9 parts per 100 000 in the second foot, and from 2 to 9 parts per 100 000 in the third foot; while the original sand contained only from 0.5 part to 1.6 parts per 100 000, showing a very serious storage or accumulation of organic matter, especially in the upper layers. The only practical remedy for that condition of things seemed to be the taking off of at least from 6 to 9 in. of the surface of the beds, and that we have been doing. We have replaced the clogged material with 6 in. of new sand, and the result has been that the beds that showed practically no nitrification have rapidly increased in nitrification and now show 2.5 parts of nitrates per 100 000. I have here two or three photographs, taken yesterday, which may be of interest. In one, the drying out of this clogging material and the curling up is very well shown. As I have stated, the origin of the trouble may be due both to the increased strength in the sewage, the limited area of the beds, or to a large percentage of fats in the sewage; any or all of these factors producing conditions favorable to the growth of Oscillaria, which

have been found to be present in large quantities. Mr. Pratt, of the Rhode Island State Board of Health, which is coöperating with us in the study of our filtration work, suggests that I speak of this growth of micro-organisms, which, under the microscope, has been found to be Oscillaria. We have found that, given favorable conditions, this growth spreads very rapidly, and, as indicated by figures I have here, a bed that was cleaned on the 21st of September, after receiving about ten doses of sewage, or a total of 320 000 gal., was in such a condition on the 2d of October that it was left to dry out and will have to be cleaned again. Many of these beds have been in operation since 1894, and have been receiving sewage at the rate before stated. They have been scraped in the fall and in the spring, and have been furrowed during the winter. The furrowing of the beds will undoubtedly cause a mixing of the foreign matter near the surface with the better sand lower down, and this foreign matter will penetrate lower when the furrowing is done with a plow than when it is done by hoeing, but my experience has been that the sewage is better taken care of during the winter season by furrowed beds than it can be by level beds; and I think, notwithstanding the results that we have experienced at Pawtucket, that we shall continue to furrow the beds. We will probably find that it will be cheaper and the results for winter purification better by that method than by any other that I know of; first passing the sewage through the grit chambers, in which the flow is greatly reduced and a large amount of sludge is screened from it, and then through the settling tanks before turning it on to the beds.

One thought arises in my mind regarding the change in the depth of the deposit of sludge in the septic tank and in the thickness of the scum, to which Mr. Eddy referred. My own experience has indicated that that is true, and I have found — and, I think, established without question — that the sludge accumulating in the bottom will suddenly rise and will become scum. And my own thought in that direction, regarding the sampling of the septic effluent and the analysis for the suspended matter in such effluent, questions very seriously whether the results obtained are absolutely correct. I do not know what method may have been pursued in the sampling of such effluent in this instance, but, unless samples are taken continuously, some time that sludge will rise from the bottom, and when it does, in my opinion, a very large amount of suspended matter is going to pass out through the effluent, of which we have obtained no

record. In that respect it is a question, in my mind, whether the results obtained from our analyses do not give more credit to the septic tank than actually belongs to it.

Mr. Weston. — How old is your sewage when it goes on the beds?

Mr. Carpenter. — Our sewage is comparatively fresh. It runs but a short distance in the main sewer, and after passing through the screen chamber remains but a few hours in the settling tanks before being turned on to the beds.

A Member. — Mr. Carpenter spoke of the beds having been overdosed. I should like to ask if it is the feeling that if they had not been overdosed this clogging deep down would not ultimately have occurred.

Mr. Carpenter. — I am inclined to think that there might have been some. I doubt if it would have penetrated as deeply as it has. I think it would have been confined more closely to the upper layers. I think the clogging of the upper layers and continued dosing prevent thorough oxidation of the sewage throughout the bed.

Mr. R. S. Weston. — The speaker has had a case similar to that of which Mr. Carpenter has spoken, where the same phenomena were observed. The bed treated with septic effluent was overdosed; it clogged 5 in. below the surface. The sand was removed to a depth of 6 in. and the bed was restored to its former efficiency. In this case there were about 600 people to the acre, and the beds were dosed from four to five times daily on alternate days. There was a great deal of soapy household waste from a large laundry.

Mr. H. W. Clark. — There is a great deal to be said in regard to the part that the matters in suspension in sewage play in sewage purification. There have been sand filters in operation at the Lawrence Experiment Station for nearly nineteen years. Thirteen years ago some of those filters became so badly clogged near the surface on account of the accumulation of matters strained out from the sewage that this clogged sand, six or eight inches in depth, was removed and new sand placed in the upper portion of several filters in order to maintain them in operation and obtain good effluents. Since then, with rather different care of the filters, they have been operated without any extreme difficulty on account of the accumulation of matter and are now operated at practically the same rate that they have been at any time during the past thirteen years. Two or three years ago, however, these filters again became so clogged as to prevent

quite as good purification as during previous years, although they did not refuse to allow sewage to pass into them easily and at sufficiently high rates. At that time the upper layers contained a great deal of organic matter, fully as much as the beds that Mr. Carpenter has just spoken of. We have tried various methods to get rid of that stored organic matter without removing the sand, but only a small percentage has disappeared in spite of the opportunity given for the upper layers to rest without the application of sewage. It looks now as if it were only a question of time when the upper six or eight inches of sand in these filters will have to be removed again, but as they have already run thirteen years and can probably run quite a number of years yet before this removal, it is, of course, a much less serious matter than if sand removal had to be resorted to frequently. The filters have been operated at a rate purposely kept low enough to prevent rapid and undue clogging. There is a great deal said at the present time in regard to the operation of sand filters at higher rates than followed with these filters, and many filters at Lawrence have been operated at higher rates. These higher rates mean simply, however, the more rapid clogging of the material and more frequent sand removal. For instance, we have operated at Lawrence for the past eight years a small filter to which septic sewage has been applied and the average rate of operation during this period has been 250 000 gal. per acre per day. During this period, we have had to remove sand twice on account of clogging and the sand removed has amounted to about 2.85 cu. yd. to each million gallons of sewage applied. The relation of the sewage applied to the suspended matter in the sand and sand removal has been as follows: There have been 805 lb. of this suspended matter in each million gallons of sewage, and we have had to remove for each 250 lb. of this suspended matter applied, 1 cu. yd. of sand in order that the filter might be operated at the high rate that I have just stated. Two other sand filters have been operated to which the effluents from trickling filters have been applied after these effluents have passed through tanks in order that a certain amount of sedimentation might take place. One of these filters has received this effluent at the rate of 600 000 gal. per acre daily, and one at the rate of 700 000 gal. per acre daily. In order to keep the rates up to this high point, we have had to remove from these filters about 3 cu. yd. of surface sand per million gallons of sewage applied. There has been about 200 lb. of suspended matter in each million gallons of the effluent of the

trickling filters applied to these sand filters, and in order to keep the rates at the high figures that I have just mentioned, we have had to remove a cubic yard of sand for every 70 lb. of suspended matter applied. These figures show that the amount of suspended matter removed from sewage that can be allowed to accumulate in the filter before sand removal becomes necessary decreases in amount very rapidly as the rate of filtration maintained is increased.

This is, perhaps, hardly a discussion of Mr. Eddy's paper, but I did not have a chance to read carefully the advance copy of it forwarded to me before this meeting, and I think you will all agree after hearing it that it is a paper that must be read very carefully in order to be able to discuss it to any great extent.

Prof. C.-E. A. Winslow. — I have listened with a great deal of interest to this paper. There is no more important question in sewage disposal than this question of the removal of suspended solids, and it is one for light on which we must look particularly to such experiments as those carried out at Worcester. I think that all of our laboratory and experiment station work, although trustworthy with regard to soluble constituents and the chemical changes which take place in sewage, is pretty sure to be more or less weak with regard to suspended solids, because the treatment of suspended solids on an experimental scale, where the sewage is pumped through a small, and it may be a complicated, pipe system, and possibly passed through one or two tanks, is very different from the problem on a large scale and under actual working conditions.

I do not like to say it in Professor Sedgwick's absence, but I think when I was a student at the Institute that he taught me there was no sludge produced in sand filtration. It seems pretty clear to-day that there is just as much sludge produced by that process as by any other process for the removal of solids. I was very much surprised when I began to look into the Brockton figures. They take from their beds alone nearly six tons of sludge per million gallons of sewage filtered, and that compares fairly well with the amount of sludge produced in chemical precipitation. It is always difficult to compare the results obtained at different places, and I should like at this time to suggest four things which ought to be studied in any consideration of the removal of solids, and about which data should be recorded in every paper on the subject. In the first place, in measuring the efficiency of the process, we ought to know always the number of parts per million of suspended matter in the

sewage and the per cent. of removal. Then, considering the sludge, I think we ought always to know the volume of sludge produced per volume of sewage treated and the percentage of solids in the sludge.

I took up two or three reports on my desk this afternoon and tried to compare results at Worcester with those at Columbus and with some of our own at the Technology experiment station. I found certain striking differences. At Worcester, with a treatment of sewage containing on the average about 300 parts of suspended matter per million, chemical precipitation took out 80 per cent., sedimentation only 52 per cent. and septic treatment 33 per cent. of the suspended solids. On the other hand, at Columbus, with 209 parts of suspended matter per million, chemical precipitation produced the same result, 81 per cent. removal, while sedimentation was more efficient and septic treatment much more efficient than at Worcester, each giving between 60 and 70 per cent. removal. At the Technology experiment station, with sewage containing 134 parts of solids, our septic tanks gave only 36 per cent. removal, about the same as the results at Worcester. The reason for these discrepancies I do not know — whether it is due to difference in the bacterial flora of the sewage, in its chemical composition or in the construction of the tanks. Any of those three things may operate.

In order to compare the character of the sludge produced I have prepared the following table. In the first column is the volume of sludge produced per million gallons of sewage treated; in the second column the percentage of solids in sludge, and in the third the number of parts of solid sludge per million parts of sewage treated.

Table Showing Amount and Character of Sludge from Various Processes.

Place.	Process.	Volume Sludge per Million Volumes Sewage.	Per Cent. Solids in Sludge.	Solids in Sludge per Million Parts Sewage.
Worcester	C. P.	4 900	8	400
	S. T.	500	6	30
	Sed.	2 500	6	150
Columbus.....	C. P.	2 300	8	180
	S. T.	540	15	80
	Sed.	1 100	13	140
Boston........	S. T.	850–2 700	2	20–50

It will be noticed that the Worcester problem is particularly serious, the sludge produced by precipitation being much in excess of that at Columbus. This would naturally be expected

from the large amount of solids and trade wastes in the sewage. Comparing the three processes studied at Worcester, it appears that septic tank, sedimentation and chemical treatment stand to each other in the ratio of 10 : 50 : 133 with regard to the amount of solid sludge produced, a pretty good showing for the septic tank.

On the other hand, the Columbus results are quite anomalous. The sludge produced by chemical treatment is exceptionally small in amount and the septic tank solids abnormally large in proportion to sewage treated. Thus the ratios for solid sludge produced by septic tank, sedimentation and precipitation are 10 : 17 : 22.

On the whole it appears that at Worcester chemical treatment produces good purification with very heavy sludge, sedimentation a fair effluent with moderate sludge, and the septic tank a poorer effluent with very little sludge. At Columbus, on the other hand, the sludge produced by chemical treatment is small in amount and the sedimentation and septic processes produce effluents nearly as good as those from precipitation so that the processes are much more alike in their results. Our results with the septic tank at the Technology station are very like those attained at Worcester. The lower of the two figures for the amount of sludge is the one to be taken for comparison, for the larger one is for tanks operated at rates too slow for maximum efficiency. We have found that the slower the rate the less the solution of the sludge, other things being equal — I mean with rates covering periods varying between 12 and 48 hr. I should like to say in passing that I appreciate very fully what Mr. Carpenter has said about the error in measuring septic efficiency, due to the carrying over of suspended solids. We have found that a very important and a very serious factor, but it is a point which I think may be minimized by careful construction of the septic tank.

We have found in our experiments on the treatment of Boston sewage that at least three processes of sludge removal are probably necessary. As our experiments have gone on, the complex nature of the problem has become more and more apparent. In the first place, for the removal of heavy suspended solids there must be some sort of grit-chamber treatment. I agree with Mr. Carpenter that the more thorough and efficient this process is made the better off we are. If the road detritus can be got out in a condition in which it is comparatively harmless — that is, in which it is largely inorganic — it is a great

gain. We take out 0.65 cu. yd. or 130 gal. per million gallons of sewage treated against 0.16 cu. yd. or 32 gal. per million gallons of sewage treated, at Worcester, a considerably larger amount. Yet our grit-chamber detritus contains 73 per cent. of solid matter against 50 per cent. at Worcester, and ours is inoffensive in character, while that obtained at Worcester is not. I suppose this difference is due to the larger proportion of street washings in our sewage; at least, there must be a larger proportion of inorganic matter. Next, we find that septic treatment gives fairly good results for our purposes. Although we get only 36 per cent. removal of suspended solids, that appears to be sufficient to enable us to operate our trickling filters satisfactorily. I was interested to see in Mr. Whipple's paper last spring a reference to the hydrolytic tank at Hampton, England (constructed by the authorities after a suggestion made by Mr. Clark in the 1899 report of the Massachusetts State Board of Health), in which the sludge is separated from the sewage in a septic tank, made into three compartments, and the sludge is allowed to undergo a long anaërobic putrefaction, whereas the sewage passes off rapidly. Our experiments have, however, indicated that even the liquefaction of sludge is interfered with seriously by a too prolonged period of septic action. Finally, in our experiments a third process of sludge removal is necessary. Following the trickling filter there must be another period of sedimentation and a further production of sludge if a clear effluent is desired. In many cases that would not be essential. In discharging into a large stream, or into the sea, it would not be necessary, because the effluent which comes from the trickling filter though turbid is stable and well purified. The sludge, like that of the grit chamber, is inoffensive in character and may be easily disposed of on land.

There must always be sludge. There is no question about that. We have not yet found any process for entirely liquefying the suspended solids in sewage. The aim of sewage treatment must be to make the sludge as small in amount as possible and as nearly inoffensive in character. We have really only three main processes in the whole art of sewage treatment, and the problem for us to solve is the proper application of those three processes in different combinations. First, either by straining or sedimentation, or by that combination of straining and sedimentation which chemical sedimentation offers, we may separate the sludge from the liquid matter. Then the liquid part must be nitrified; and some of the sludge may be digested in the

septic tank. It seems to me that we ought to keep those processes separate in our minds, for all others are based on them,— straining or sedimentation for the separation of solid and liquid matter, septic treatment for the partial liquefaction of sludg and aërobic bacterial treatment for the oxidation of solids or liquids, or all combined.

Mr. Carpenter. — Just one thought occurred to me as I listened to the last speaker, which relates to the correct calculation of the total amount of sludge deposited in the septic tank. I question whether we do not, in some instances, give the septic tank credit for more than it accomplishes. When the septic tank is drawn down, preparatory to measuring the sludge, the effluent or liquid drawn off at that time will contain a large amount of matter in suspension. Do we always sample that and take account of the suspended matter that passes off in that way and add it to the sludges found in the tank? I did not do so at first.

Professor Winslow. — In our experiments we stirred up the entire contents of the septic tank and considered the whole septic tank contents as sludge, which is the reason our "sludge" contained only 2 per cent of solids.

Mr. Carpenter. — If your septic tank had been of considerable size, it would have been difficult to have stirred it up and have secured an average sample.

Mr. Fales. — In our septic tank, we took a small sample, and were very careful to draw it off at a time when there was a very large ebullition, and analyzed it and found it analyzed about the same — that is, for a 250 000-gal. rate, which was the lowest rate used.

Mr. Carpenter. — Did you take continuous samples?

Mr. Fales. — Yes, samples every 10 or 15 minutes. Then in regard to sampling the septic effluent, we sampled every hour; but I never noticed a time when the septic tank sent up a very large quantity of sludge as compared with the quantity sent up at other times. The results seemed to be very uniform, and in taking samples of the effluent I feel that we got good average samples throughout, taking it once an hour through periods of a month.

Mr. Carpenter. — Did you find at times that a large amount of sludge would come from the bottom to the top?

Mr. Fales. — Yes, after a rainstorm particularly; we found that a rain storm with wind would drive the sludge to the bottom and the next day it would nearly all be back again.

But it didn't take place in an hour. It would take place during a period of 24 or 48 hr.

Mr. Eddy. — It ought to be made plain that these hourly samples were continued through the 24 hr. of the day and every day in the period, and not during a 10-hr. day.

Mr. E. B. Phelps. — There have recently come under my observation two septic tanks which are so alike in their method of operation and so unlike in their results that they present an interesting problem. Both are situated in New Jersey; both were put in operation about the same time, in 1902. One is at Red Bank, N. J. This tank is a homemade affair, made out of an old gas holder, circular and about 43 ft. in diameter, with a conical bottom, so that the center depth is about 5 ft. and the depth at the edge about 9 ft. Its capacity is 100 000 gal., and the estimated daily flow of sewage is 250 000 gal., although that varies widely, there being a great deal of storm water, not only from surface openings but from leakage into the sewer. The tank was put in operation in 1902 and has never been touched from that day to this. At present there is almost nothing on the bottom, but on the surface there is a scum fully 2½ ft. thick of the cleanest, nicest sort of stuff I ever saw in a septic tank. It is supporting quite a growth of mushrooms and vegetable matter of different sorts, and, when broken into, presents an appearance not unlike garden soil — rich, sandy loam. Now, in contrast with that is the other tank I have in mind, which is located at Plainfield, N. J. It was built at the same time and has a capacity of about half a million gallons, with a daily flow of 1 000 000 gal., so that its period of storage is about 12 hr. That tank, from the time it went into operation to the present time has required cleaning at least twice a year and often more frequently. It collects immense volumes of sludge. The scum is a foot thick generally before cleaning, and this is exceedingly foul-smelling stuff, so that it is necessary to deodorize it with lime or something of that sort before it can be handled; and although it is located at a considerable distance out in the country, the nuisance is pretty bad; it is noticeable for a long distance — in fact, was very noticeable a quarter of a mile away when I was last there. Moreover, the Red Bank effluent was quite clear and free from suspended matter, while that from Plainfield contained more of such suspended material than one expects to see in a good tank effluent. I haven't any explanation to offer for the difference in the action of these tanks. The analyses of sewage are not dissimilar, and I can find no reason

for the difference, unless it be the fact that the tank I mentioned first, having a diameter of 43 ft., has a mean velocity through it of 86 ft. a day, and I suppose the maximum velocity is not over 100 ft.; the other tank is 100 ft. long, as I remember it, so that the velocity is over 200 ft. per day. Mr. Eddy's figures on sedimentation were interesting to me because they seemed to show more value in slow velocities and longer time than we had hitherto expected. I think it has been the general experience that after two or three hours' sedimentation the contents of the tank are not much further clarified in the next 24. Mr. Eddy finds that up to 24 hr. and longer, sedimentation is quite active, a very important matter. And that is the only thing I think of in this connection to explain the results. I thought it was a very interesting matter and worth presenting to you.

MR. WESTON. — I would ask Mr. Phelps if the character of the sewage in the two tanks he mentioned is the same with respect to its being manufacturing or domestic.

MR. PHELPS. — Yes, both are strictly domestic, so far as I know. The character of the analyses would indicate that the sewages are quite similar.

MR. CARPENTER. — There is one question I should like to ask Mr. Eddy, and that is as to the comparative quality of the effluents from the several methods of filtration.

MR. EDDY. — That is going a little outside the scope of the paper, and for that reason it was not mentioned. The paper deals only with suspended matter. I should say that the quality of the effluent from the filters receiving the effluent from chemical precipitation was the best, as we have operated our filters. By way of explanation, I might say that we have only a very small proportion of the filtering area which would be necessary to treat all of our sewage, and our object in life is to get the best possible net result, which does not necessarily mean the highest degree of purity of effluent. That is, if we can get a large amount of water through our beds with a fair degree of purity we are obtaining better net results than if we get a higher degree of purity with a very small amount of water. Consequently, the question of purity is not as finely drawn as in other places. The filtrates from unsettled and settled sewage have not been very different, and in fact our effluents by the various processes have not varied materially in quality. None of them show a high degree of purity on account of the very large dosing which the filters have received. Our last annual report gives comparative rates for all the processes, does it not, Mr. Fales?

Mr. Fales. — Yes, comparative rates of flow and comparative analyses.

Mr. Eddy. — So that I should have to refer you to the report to get that question thoroughly answered. There was one other question raised by Mr. Carpenter which it might be interesting for me to touch on, and that is the question of furrowing beds for winter use, presumably largely to keep the ice off the surface. We accomplish the same thing without furrowing, by retaining on the surface of the beds a few of the piles of scrapings. That is, in the fall we take off just a sufficient number of piles to leave at regular intervals small heaps of scrapings, and those are sufficient to keep the ice off and accomplish the same result as by furrowing, thus avoiding mixing the large amount of organic matter in the surface layers with the cleaner sand below.

Mr. R. S. Weston. — Although the hour is quite late, the speaker would like to bring to mind the general question, namely, What is suspended matter? It has been shown that the effluent from the septic tank at Worcester clogs the filters faster than the effluent from the sedimentation tank. What is the reason for this?

German * and English † investigators perhaps give data which explain the experience at Worcester.

Fowler and Ardern showed that settled sewage contains 25 per cent. septic settled liquor, 47.6 per cent. of the organic matter in the form of colloids, as shown by the oxygen consumed test, and 52 and 61 per cent., respectively, as shown by the albuminoid ammonia test.

O'Shaughnessy and Kinnersley ‡ showed that the proportion of colloidal matter in samples of sewage varies greatly with various methods of treatment. Fecal liquors were found to contain from 46 to 86 per cent. of the organic matter in the form of colloids, while urine contained from about 7 to about 10 per cent. The organic matter in Birmingham crude sewage contains about 40 per cent of colloids on the average, the amount

* W. Blitz and O. Kroehnke: "Organic Colloids from Town Sewage." *Berichte der deutschen chemischen Gesellschaft*, Vol. xxxvii, p. 1745.

† Jones and Travis: "Elimination of Suspended Solids and Colloidal Matters from Sewage." Proceedings of the Institution of Civil Engineers, 1905–6.

Fowler and Ardern: "Suspended Matter in Sewage and Effluent." Journal Society of Chemical Industry, 1905, 483.

‡ "Journal Society of Chemical Industry, 1906, 719.

varying greatly with the character of the sewage, for while the organic matter in manufacturing waste contains only 7.5 per cent. of colloids, settled Ashton sewage, which is a stale domestic sewage, contains 72 per cent.

The investigators show that fecal matter passes into semi-solution or into the colloidal state upon agitation with water, and the amount passing over into the colloidal form depends upon the time of contact and the degree of agitation of the mixture of fecal matter and water. These authors believe that the action of the septic tank reduces the sludge by decreasing the true suspended matter and increasing the colloidal matter, more than by true anaërobic solution. Do not the results of these experiments explain some of the differences in efficiency obtained at various places? Do not analysts determine suspended matter differently? Do not the errors of determination obscure the lessons to be learned from many of our experiments, because one considers as dissolved what is really semi-soluble?

I think we can depend upon the accuracy of the experiments made abroad, and the practical bearing is important, because if sewage containing a large amount of colloidal matter be applied to disposal beds, it reseparates, sometimes beneath the surface of the bed, and causes clogging.

There is a great chance for study and development along this line. If the hypothesis is correct, then treatment of the sewage should be such as will produce the least colloidal matter. If this is true, the liquid portions of the sewage should be separated from the sludge as quickly as possible and, as Mr. Clark has suggested as long ago as 1898, the sludge should be treated separately. To express it differently, practice should aim toward getting as much matter as possible into the insoluble form as quickly as possible, removing it, and allowing the rest of the sewage to be treated on trickling filters or disposal beds.

It may be possible that the presence of colloids in septic tank effluents is a better explanation of the difficulties experienced in treating the same on disposal beds than is the theory that the toxins produced by the anaërobic bacteria in a septic tank inhibit the growth of the aërobic bacteria in the disposal beds, which belief has led to the construction of aërators between septic tank and disposal beds.

This paper certainly is very suggestive and throws much light upon a somewhat obscure problem.

Mr. Fales. — Mr. Carpenter states that analyses of the influent and effluent are likely to give the septic tank credit

for accomplishing more than it actually does on account of inaccurate sampling of the effluent. At times, as Mr. Carpenter suggests, a large amount of sludge rises in the tank, at which times an abnormal amount of suspended matter is carried out of the tank in the effluent. It is necessary to sample a fair proportion of this. I should think in order to obtain a fair sample of the septic tank effluent for a single day when the tank is in active fermentation, samples would need to be taken as often as every 15 minutes. Through a period of 4 weeks or more, if the samples are taken as they were in Worcester every hour, 24 hr. in the day, 7 days a week, I believe fair samples will be obtained.

Mr. J. W. Bugbee (*by letter*). — Owing to the fact that the sewage of Providence is pumped to an elevation of 27 ft. before its arrival at the precipitation tanks, no trouble with road detritus and other heavy sediment has been encountered as at Worcester, where the gravity system is in use. During the five years since the plant was put in operation, no sediment has accumulated in the tanks which could not be made to flow to the sludge ejectors, and be disposed of in the usual way, and the sludge drains and well yield only 5 or 10 yd. of sand in an annual cleaning.

A large sump in the main sewer, just above the pumping station, takes the place of the grit chambers, and the thorough screening which the sewage receives before passing to the pumps removes all the coarser floating matter.

The suspended matter remaining in the sewage is still further subdivided by the action of the pumps, and arrives at the tanks in the form of very small particles. For these reasons the sludge formed by the chemical treatment is more uniform in composition and contains a somewhat greater percentage of organic matter than is the case at Worcester.

Other points of difference in the Providence sewage are the absence of pickling liquids, and the presence of large amounts of waste from the woolen mills. This waste contains, in addition to dyestuffs, the wool-grease from the scouring-machines, and soap from the cloth washers.

The average amount of fat in the dried sludge has been found to be about 13 per cent.

The presence of large amounts of acid in the Worcester sewage probably accounts for the length of time (2 to 4 weeks) between cleanings of precipitation tanks, for it has been found necessary in Providence to clean all tanks at least once a week

in warm weather to prevent fermentation of the sludge. Also the lime necessary to assure economical pressing is less in Providence, as 60 lb. has been found to be the maximum amount required, even though septic action may have been going on for some time before the removal of the sludge from the precipitation tanks.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by January 1, 1907, for publication in a subsequent number of the JOURNAL.]

DISCUSSION ON MR. SPOFFORD'S PAPER, "THE NORTHERN BOUNDARY OF MASSACHUSETTS."

Mr. George A. King. — Several years since, while waiting on the wharf at the Weirs, my attention was attracted to a small structure at the outlet to Lake Winnepesaukee, and I copied the enclosed inscription found therein, which may be interesting.

ENDICOTT ROCK.
The name of
Iohn Endicott Gov.
and the initials of
Edward Johnson and Simon Willard
Commissioners
of the Massachusetts Bay Colony and
John Sherman and Jonathan Ince
Surveyors,
were inscribed upon this rock Aug. 1, 1652
to mark the head of Merrimack River.
A line three miles northward of this rock was
then claimed by that colony as the northern
limit of their patent.

E I — S W
W P

IOHN
ENDICVT
GOV

I S — I I

The structure which covers
this historic stone long known
as Endicott Rock was erected
for its protection in 1892 by the
State of New Hampshire in
accordance with joint resolutions
of its legislature approved
Sept. 7, 1883 and Aug. 1885.

John Kimball, Erastus P. Jewell, Joseph B. Walker, Commrs.

Fred Brooks, Secretary. — Shortly before the sudden death of Mr. Spofford he submitted a draft of discussion which he had prepared in reply especially to Mr. Hodgdon's criticism, pages 16–19.

He remarked that the first half or more of his paper, ten pages out of sixteen, was a relation of simple historical facts.

He said that under the legislative enactments of Massachusetts, New Hampshire and Vermont, 1885–92, neither the

surveyors nor the commissioners were authorized to *change* any line; that they were not even authorized to survey a conventional line and suggest some changes that might be needed; that their business was solely to run the lines by the monuments, straight or crooked, to replace old monuments if required, and to furnish and set all new ones required, then to map their lines and to report the whole business to the legislatures of their respective states; that when he wrote the Resolve that passed the Massachusetts legislature in 1885 he had no idea that it would require the approval of Congress.

He asserted that he never said or wrote anywhere or at any time that two states were not competent to *establish* a state line, because it was a well-known principle of law that they could do it legally, precisely in the same manner that two towns could agree upon a boundary line, and two individuals also; that this was too simple a principle to need any illustration; and was a matter of daily occurrence between individuals.

His contention was that two states were not competent to *change* an established state line. He said that two individuals could not change the line between their respective premises without a deed signed by both parties and duly acknowledged; nor could two towns change a town line without authority from the state legislature; nor could two states *change* an established state line without the approval of Congress; and that in no other way and under no other circumstances could territory of one state be ceded to another state, whether the territory were one square foot or ten thousand square feet or square miles; and he cited the case of Boston Corner as a precedent that must be followed in all cases where territory was to be transferred from the jurisdiction of one state to that of another. He said he was well aware that this principle, apparently so simple, had been doubted by others.

FIG. 1. TOW-BOAT "FRED. HARTWEG": LENGTH, 160 FT.; BEAM, 29 FT.; DEPTH, $4\frac{1}{2}$ FT.; BUILT, 1896; 2 ENGINES; CYLINDERS, $18\frac{1}{2}$ IN. BY 7 FT.; 4 BOILERS, 38 IN. BY 26 FT.

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THE WESTERN RIVER STEAMBOAT.

BY THE LATE A. H. BLAISDELL, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, June 5, 1901.*]

THE type of American steamboat in use on the alluvial rivers of the West and South is often criticised. The criticism emanates, however, for the most part, from those who have given both the rivers and the boats but little study. A comparatively short experience on our rivers never fails, I have observed, in convincing the intelligent critic that our steamboat is admirably adapted for the work it is called upon to perform. The great fluctuation in stage of water, the rapid currents, the caving banks, the constant shifting of channels, the hazard of snags and flows of heavy drift, the very shoal water over crossings during much of the navigable season, the impossibility of maintaining more than a few improved landings, render the adoption of the conventional type of tide-water steamboat infeasible on alluvial rivers. The western river type of steamer is the result of a long series of trials and errors, and, until very recent years at least, it has been a well-established fact that it not only carried a greater amount of freight on a given draft of water, but that its cost of construction and outfit per ton of freight capacity was less than that of any other type of steamboat constructed in the world.

The average life of a western river hull, built of oak, does not exceed 12 years, and after a service of about 4 years its annual repair aggregates more than its first cost. The engines

*It is necessary to omit in publication a number of the illustrations that accompanied this paper.— SECRETARY, ASSOCIATION OF ENGINEERING SOCIETIES.

outlast the hulls several times over, and it is not unusual that engines are doing duty on their third or fourth hull to-day. On eastern waters a life of 40 years for a wooden steamboat hull is not uncommon.

Previously to the keen competition of railroads in the West, when river traffic was very extensive, the business was predicated on expectation tables of partial and complete loss based on experience. The hazards attending navigation are well exhibited in the list of steamboat wrecks on the Missouri River which have occurred since 1819. The total number of wrecks from all causes is 300, of which 210 were from snags and hidden rocks, 26 from ice, 26 from fire, 6 from boiler explosion, 10 from collision with bridges and 22 miscellaneous.

The early form of propelling machinery, the horizontal, long stroke, high-pressure, non-condensing engine, still holds its place, and rightly so; many improvements in parts have been made, but the type remains as best adapted to a service which requires primarily lightness, rapid action, absolute reliability, simplicity in construction, capability of easy repair and economy of space. There are apparent crudities in parts of the machinery, and mention is often made of the iron-strapped wooden connecting rod and the "doctor" feed pump. A trial to design a substitute for the wooden pitman, combining equal lightness and stiffness, will convince the skeptical of the fruitlessness of his effort. The "doctor" pump, with its pan or coil heater supported on its water columns, can be criticised only on account of its weight; its feed is slow and sure, and all its working parts are readily accessible and easily repaired. A lighter pattern of "doctor" pump, without the heater attachment, is in use on some few boats, but a light, inexpensive and satisfactory heater, so far as I know, has not yet been devised.

In regard to boilers, experience indicates that the externally fired, horizontal cylindrical boiler with large return flues is the best adapted for service on our silt-bearing streams, and appears to justify a former law which prohibited the use of any other type of boiler on vessels navigating rivers flowing into the Gulf of Mexico. At present, however, owing probably to superior material and workmanship, the law allows many other types of boiler to be used, and also permits an increase in thickness of shell of the externally fired boiler from a previous limit of 0.26 in. to 0.30 in. Many instances may be cited, and some of very recent date, of boilers of the locomotive type, the Scotch marine, the Clyde and other types, combining in their con-

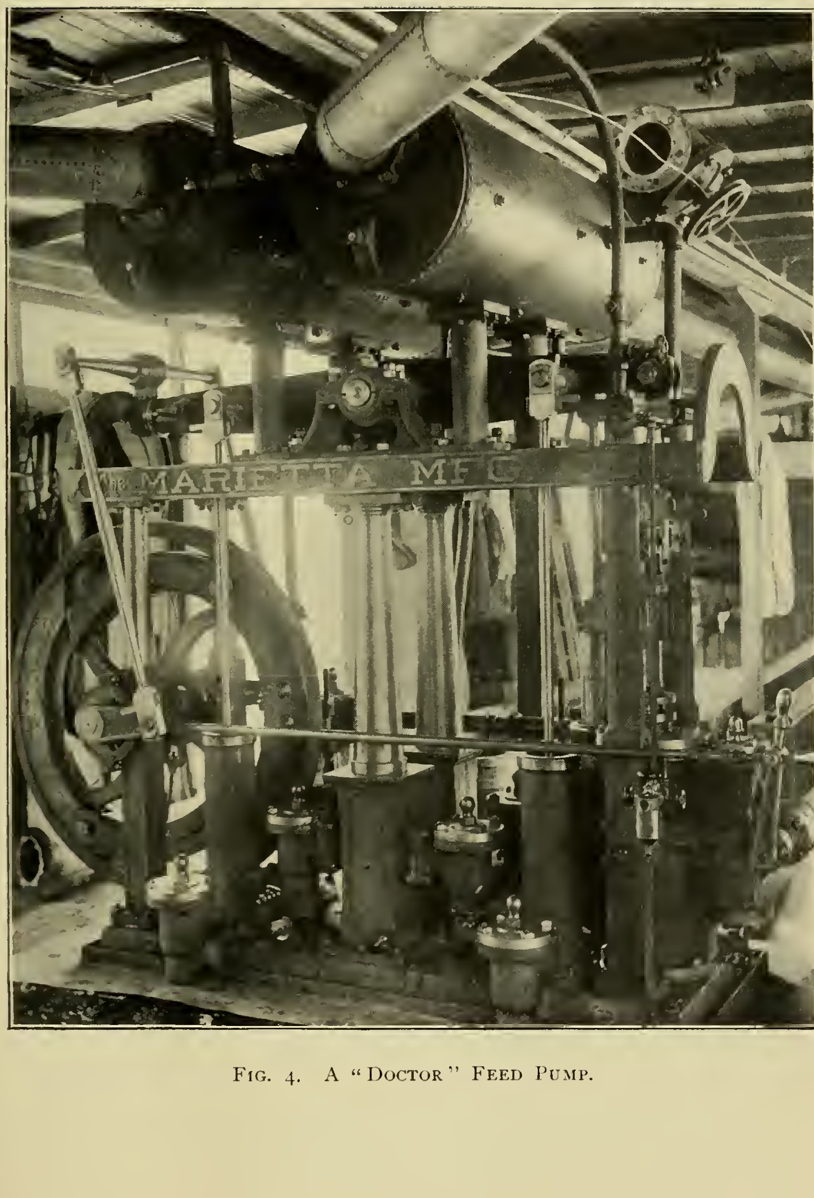


Fig. 4. A "Doctor" Feed Pump.

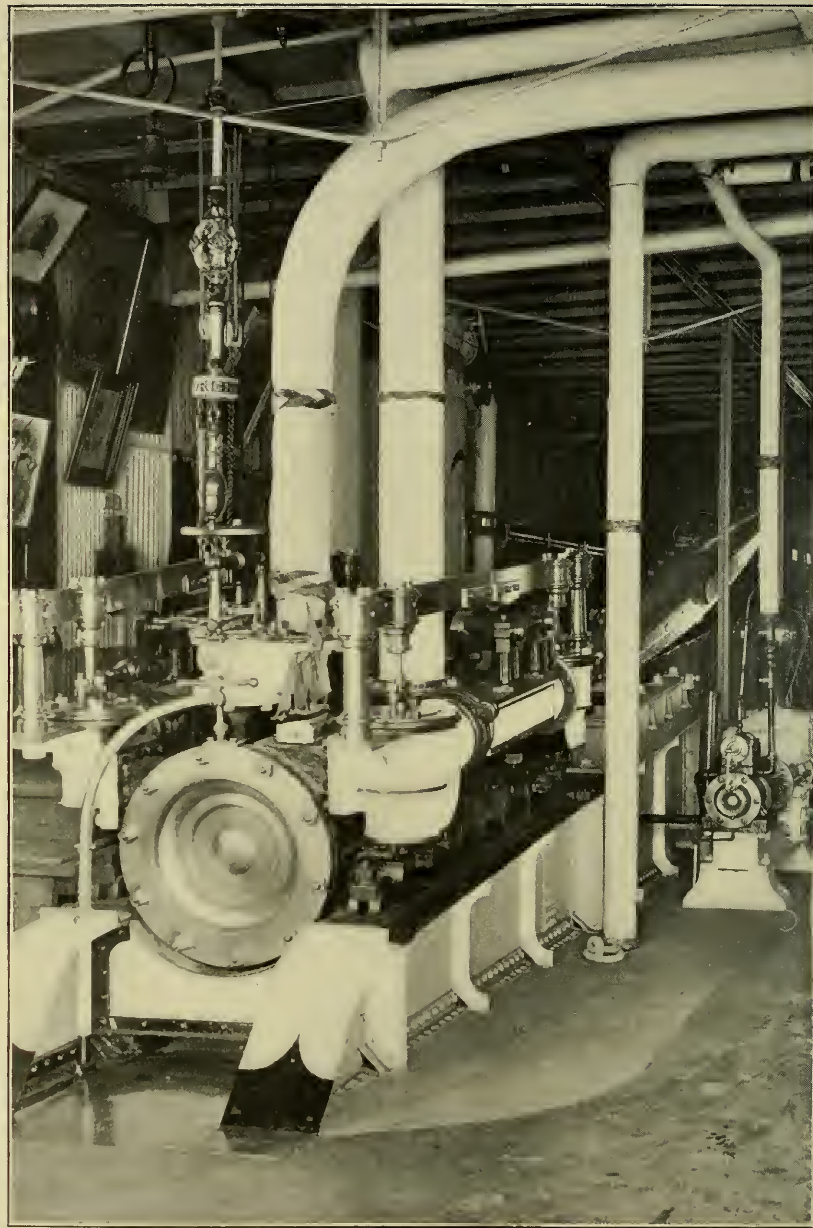


Fig. 3. One of the Engines of the U. S. Snag-boat "H. G. Wright."

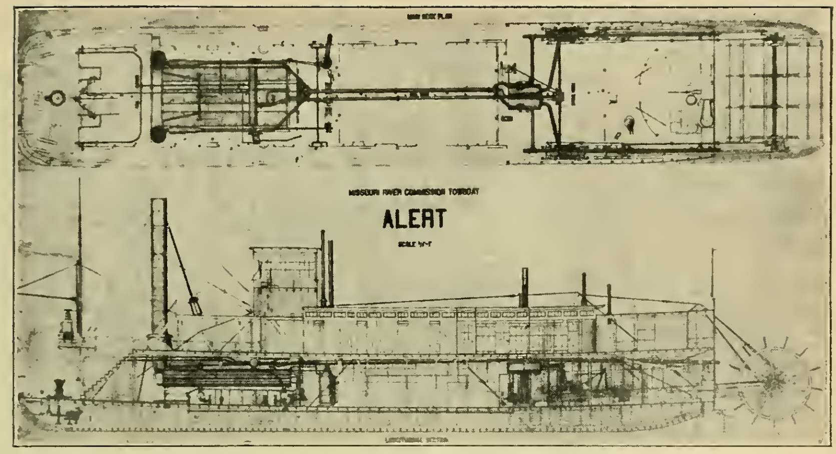


Fig. 2. Wooden Tow-boat "Alert," of the Missouri River Commission: Dimensions, 132 ft. by 24 ft. by $4\frac{1}{2}$ ft.; Engines, 15 in. Diameter by 6 ft. Stroke; 3 Boilers, 40 in. by 24 ft., each containing Two 9-in. and Two 11-in. Flues.

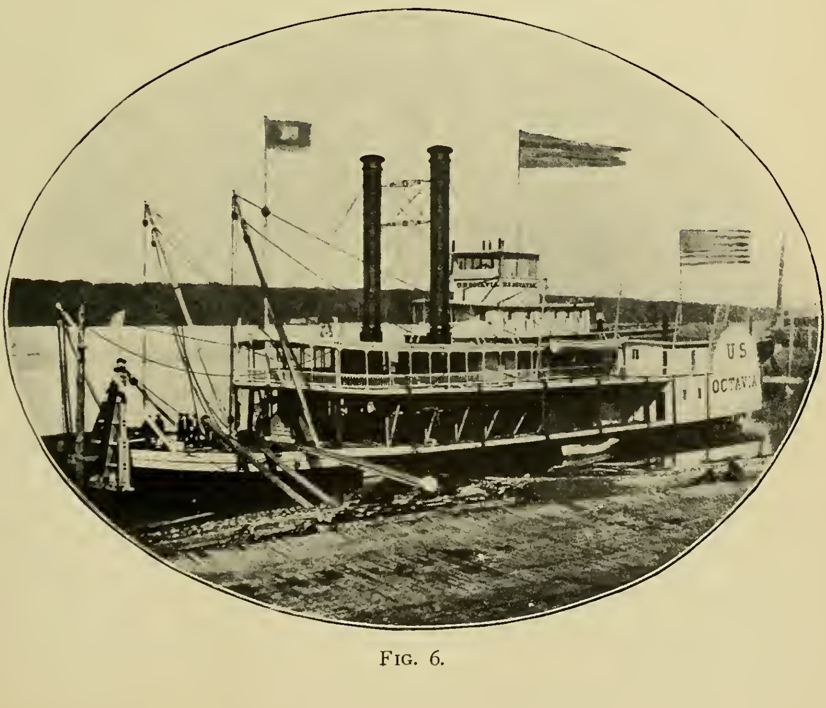


Fig. 6.

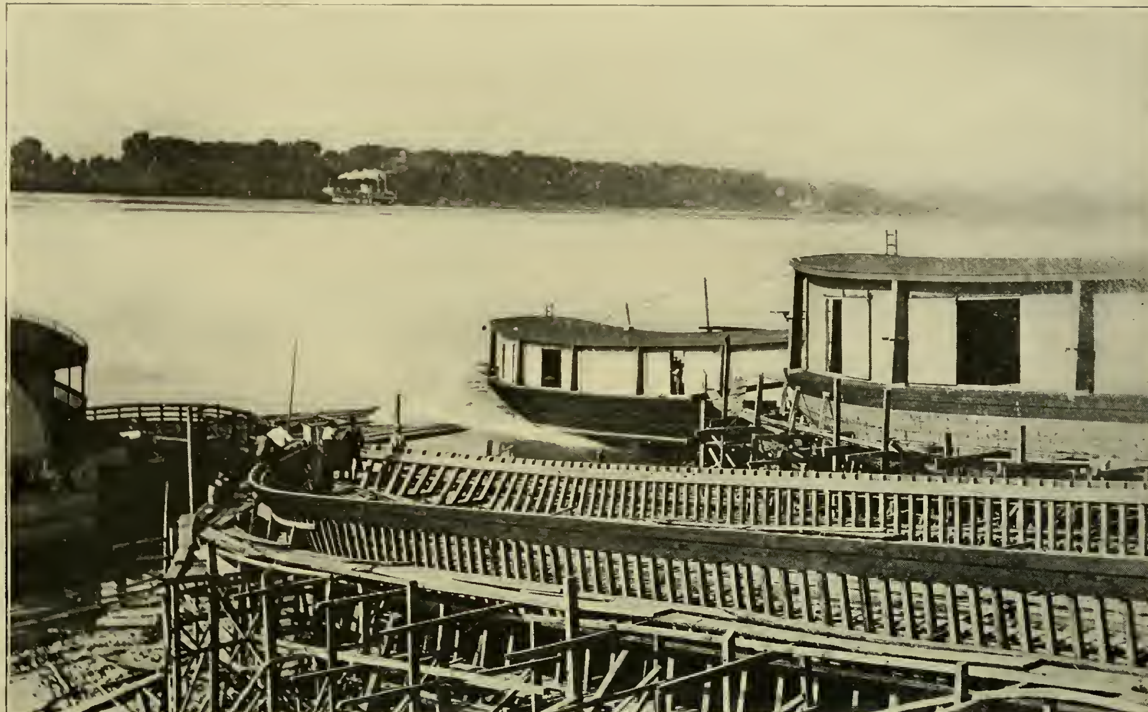


Fig. 5. Barges of the Mississippi Valley Transportation Co. Dimensions, 225 ft. by 36 ft. by 10 ft. Launching of Barge "Commerce," Howard's Shipyard, Jeffersonville, Ind., 1891.

struction the best of material and workmanship, proving complete failures in western river service, and being supplanted by the common type of externally fired horizontal boiler. The water-tube boiler has not yet, in my opinion, received a fair test on our western rivers, and whatever improvement in steam generators we may expect in the near future lies, I think, in the proper application of the water-tube type.

Passing now to the hull of the western river boat; the wooden hull admits of but little variation in manner of construction, and consists essentially of cross frames, to which the skin and deck are attached and over which are run the bulkheads, keelsons, stringers and other longitudinal fastenings. The small available depth and the nature of the material indicate a deficiency in longitudinal strength; this is made up, at least for hogging strains, by chains on each side along the cabin bulkheads, carried up above the hurricane roof and one or more interior chains under the cabin floor. The model of the hull depended on the intended service of the boat, and, perhaps above all other parts, was the result of experience. The superintendents of the different boat yards were known as specialists in some particular type of boat; as a rule their mold-loft practice was jealously guarded, and the few apprentices admitted had to rely much more on their individual effort than on instruction to gain any insight into the geometry of boat building. With no knowledge of descriptive geometry as taught in books; with an entire innocence of any definite ideas of the relative positions of centers of gravity of weights and displacement; with, generally, a contempt for any aid from mathematics or science, it is quite wonderful how expert these men became as constructors. In their best boats the scientific constructor will find but few things to condemn as regards either model or disposition and use of material. Modern literature is prolific in fulsome praise of the visible executive officers in our marine and river service, and perhaps their merits have not been too highly extolled; but the constructor and the engineer, whose duties are too material to be gushed over and too complicated to be popularly understood, are seldom mentioned and never appreciated.

In respect to the performance of western river steamers there are but few on which complete tests have been made, and of these but few details are available. The only complete tests of which I have knowledge are those made personally by Col. Charles R. Suter of the Corps of Engineers, United States Army,

than whom there is none better equipped, by experience and theoretical knowledge, to write a treatise on the subject of this paper. The tests made on one of his boats, the United States dredge boat *Octavia* (Fig. 6), were made a precedent in subsequent designs in the practice of his office. The wooden hull steamer *Octavia* was built at St. Louis, Mo., in 1866, for the "mountain" (Fort Benton) trade. Her general dimensions were: Length between perpendiculars, 199 ft. 8⅝ in.; beam, 36 ft.; depth of hold, 6 ft. She had two engines 20 in. diameter by 6 ft. stroke; three externally fired, cylindrical boilers 44 in. diameter by 24 ft. long, each containing 6 return flues, 2 of 10.5 in.; 2 of 9.5 in. and 2 of 7.5 in. diameter respectively; two side wheels, 24 ft. diameter by 10.5 ft. length of bucket; 16 buckets varying in width from 22 in. to 12 in. The boat was of the general type of successful merchant boats then building, and, because of her full forward lines, was well adapted for carrying and operating the heavy long scraper on her bow, for which use the government bought her. She had made but one trip to the mountains, the profits of which are said to have more than covered her original cost, before she was purchased by the United States. The boat was in no way remarkable except that her builders appear to have struck a happy mean in proportioning her hull and machinery. On a trial trip of 4 hours' duration in 1874, the following results were obtained:

Mean draft of boat	32½ in.
Area immersed surface	7 001 sq. ft.
Displacement	508.6 tons
Mean speed in still water	9.78 miles per hr.
Mean dip of wheels	27½ in.
Mean pressure (by gage)	134 lb.
Mean number of revolutions	18⅛
Indicated horse-power	396.37
Grate surface	52 sq. ft.
Heating surface	1 744 sq. ft.
Coal burned per hr. per sq. ft. of grate	29 lb.
Water evaporated from 212 degrees fahr. per lb. of coal	6.16 lb.
Coal burned per hr. per i.h.p	3.79 lb.
Slip of wheel	33.7 per cent.

The tests of a more recent boat are those of the stern-wheel iron steamer *Mississippi* (see Fig. 11), belonging to the Mississippi River Commission. This boat was built by the firm of Allen & Blaisdell, St. Louis, Mo., in 1882. Two purposes were to be combined in her construction — that of an inspection steamer having large cabin capacity, and that of a tow-boat.

U.S. Steamer "MISSISSIPPI"
Lines
AS MEASURED FROM MOULD LOFT

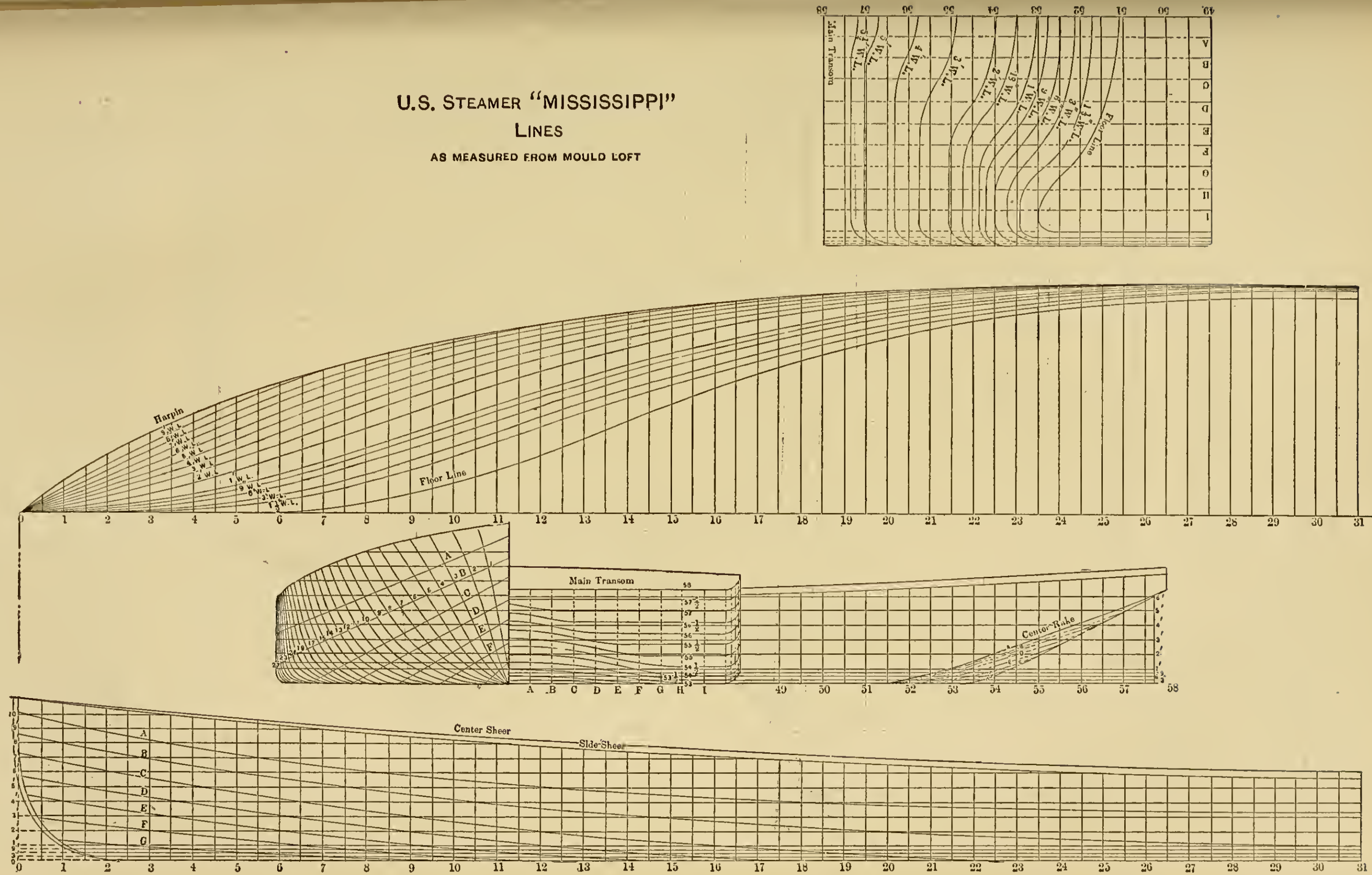


FIG. 7.

The sum of $45 000 only was available for her construction, and the work was undertaken with the understanding that her

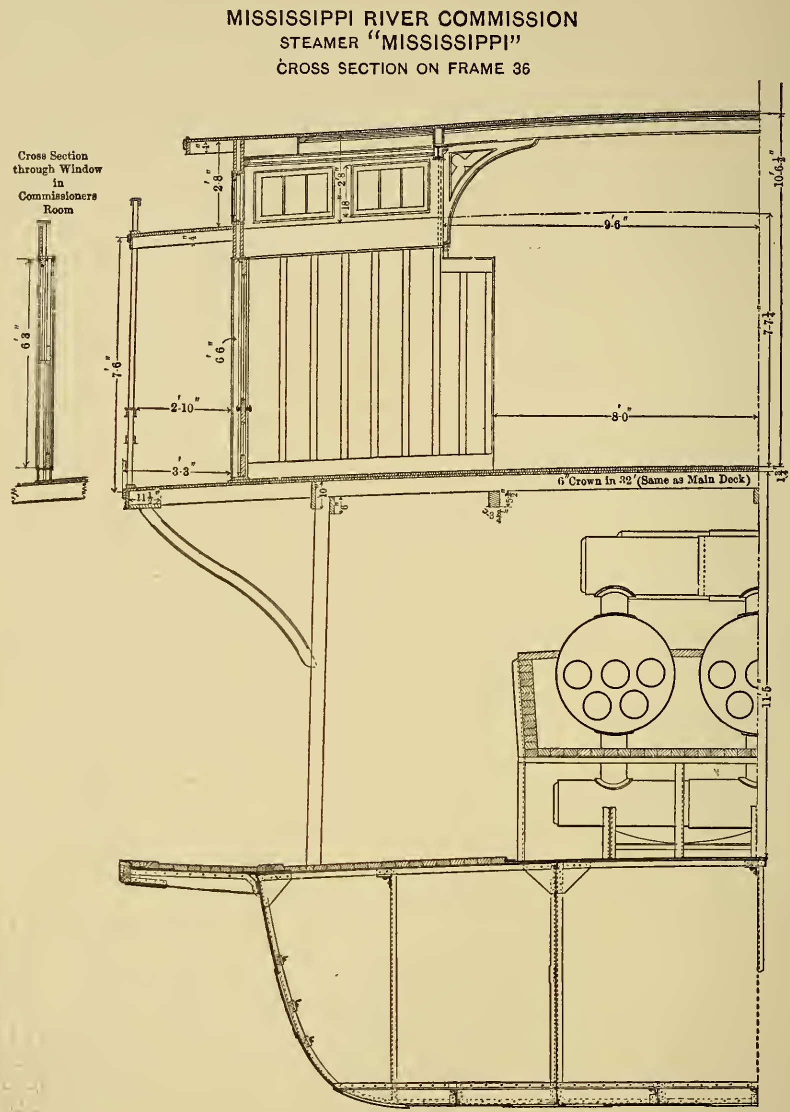


FIG. 8.

engines were to be second-hand ones, 20 in. diameter by 6 ft. stroke, which were then in store of a St. Louis wrecking company. The engines were formerly on the steamer *St. Joseph*,

which was built in 1865 and was wrecked in 1880; and, judging from their condition, might have had service previous to that

MISSISSIPPI RIVER COMMISSION
STEAMER "MISSISSIPPI"
CROSS SECTION ON FRAME 96

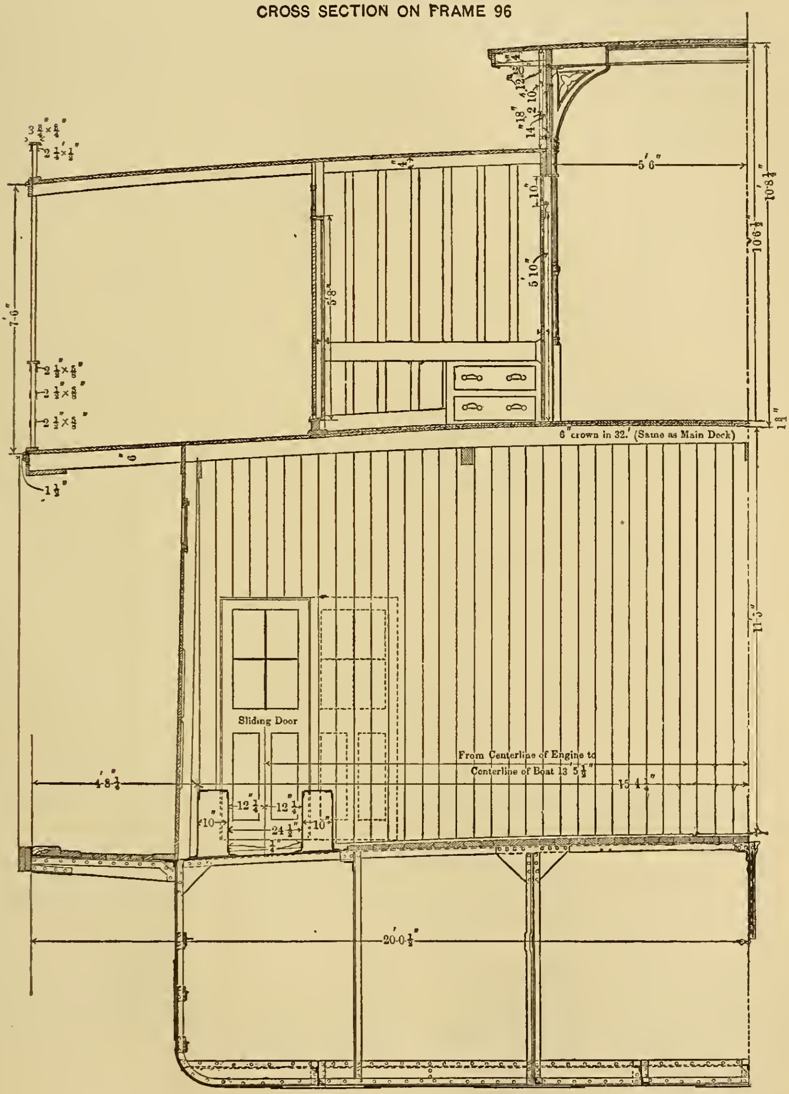


FIG. 9.

date. So many renewals were found to be necessary, including one new cylinder, that money would have been saved to the builders had entirely new machinery been purchased. Had

the cost of the boat not been so limited, her engines would not have been less than 22 in. diameter by 7 ft. stroke. Her general dimensions were: Length between perpendiculars, 174 ft.; length over all, 201 ft.; beam, molded, 32 ft.; beam, over

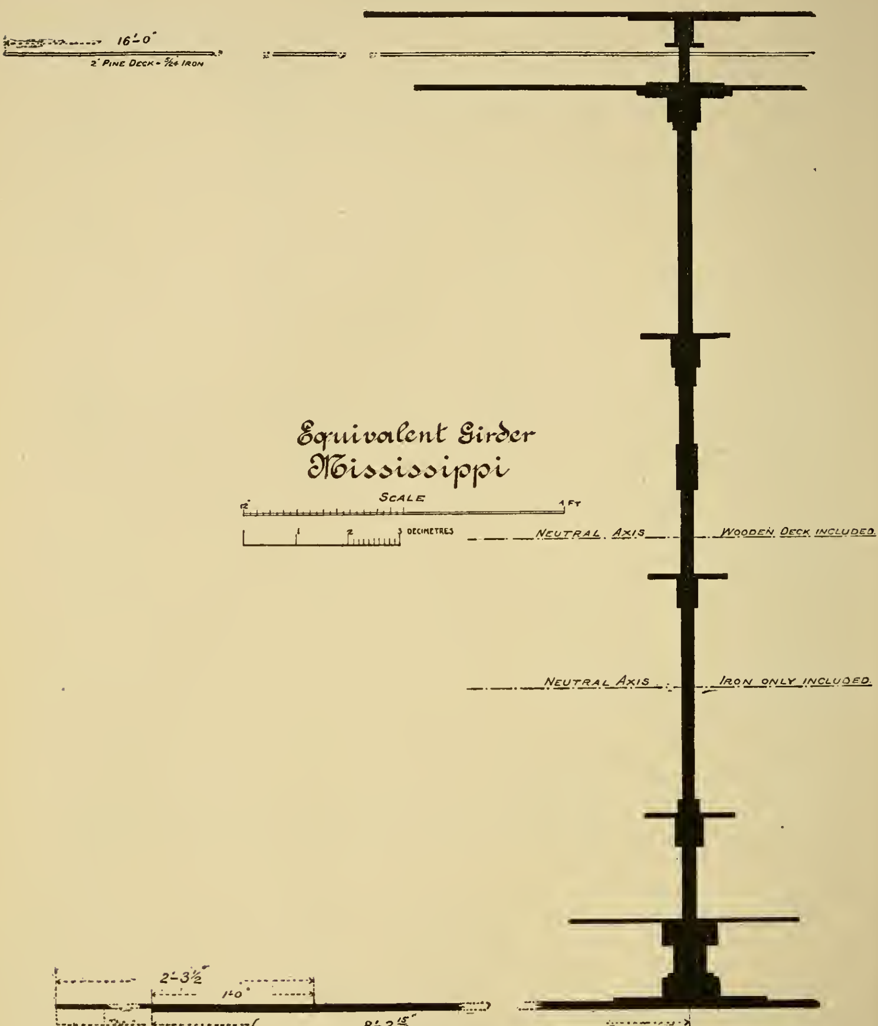


Fig. 10.

guards, 40⅔ ft.; depth, 6 ft.; sheer, forward, 5 ft.; sheer, aft, 2 ft. Two engines, 20 in. diameter by 6 ft. stroke. Three boilers, 42 in. diameter by 28⅓ ft. long, each containing 5 10-in. diameter flues. Maximum steam pressure allowed, 160

lb. Grate area, 61.4 sq. ft. Heating surface, 1 714 sq. ft. Stern wheel, 22 ft. diameter by $20\frac{5}{8}$ ft. length of bucket; 20 buckets, 24 in. in width.

The hull is constructed on the longitudinal system, with 2 longitudinal bulkheads. In the extreme portions of the bow and stern, beyond the collision cross-bulkheads, the transverse frames are brought down to the skin and made continuous for facility in construction, but the longitudinal strength is amply maintained over the cross floors. The strains which come on a boat are longitudinal, and it certainly appears logical to treat the hull as a girder. The deck of the boat is of white pine, but heavy iron plank sheers and stringer plates are run over the gunwales and bulkheads. The wooden deck is an important factor in the strength of this boat, as by iron butt-straps it is made practically one piece, excepting for the hatch openings. In calculations for strength it is usual to consider $\frac{5}{48}$ of the thickness of the wooden deck as its equivalent in iron. It will be seen in the drawing of the equivalent girder (Fig. 10) that the position of the neutral axis is well placed to resist either a hogging or a sagging strain, to either of which the boat may be subjected.

The following are the results of her trial trip, made immediately before she was put in commission, in May, 1882:

Draft of boat	46 in. forward and 40 in. aft
Area of wetted surface	5 330 sq. ft.
Displacement	454.7 tons
Boiler pressure	160 lb.
Mean pressure in cylinders	105.47 lb.
Revolutions per minute	$21\frac{5}{8}$
Indicated horse-power	507.95
Speed per hr. in still water	12.41 miles
Slip of wheel	22.2 per cent.
Coal burned per hr. per i.h.p	4.385 lb.
Coal burned per hr. per sq. ft. of grate	39.596 lb.
Water evaporated from 212 degrees fahr. per lb. of coal	4.64 lb.

The coal was the common steamboat coal furnished in this harbor.

Applying Rankine's formula for the resistance in pounds to the motion of a ship in water,

$$R = K.A.V^2,$$

in which V is the velocity of the vessel in knots; A, the augmented surface, = the wetted surface multiplied by 1 + a variable dependent on the mean sine of the angle of entrance; K, a coefficient for frictional resistance of clean painted iron at a

speed of 1 knot, = 0.01; and placing the ratio of the net h.p. to the i.h.p. at 0.613, a value determined by experiments of Rankine and others, the maximum speed to be expected for the *Mississippi* from the i.h.p. developed on the trial is 12.55 miles per hr.

In 1893 the entire upper works and most of the main deck were burned while the boat lay in winter quarters. Her hull, boilers and machinery were comparatively uninjured and she was brought to St. Louis and fitted out with a more extensive cabin, a Texas was added, and she was generally overhauled.

In 1898 her old boilers were replaced with a new battery of 3 boilers, 44 in. diameter by 28.5 ft. long, each containing $\frac{3}{9}$ in. and $\frac{2}{11}$ in. diameter flues, but having an additional thickness of shell which increased the allowable pressure to 180 lb. Fig. 11 shows the present appearance of the boat and its much criticised wheel.

The club members will recall a series of running tests made with the steamer, detailed by Mr. F. B. Maltby in his paper read March 7, 1900, on the Operations of the Hydraulic Dredges of the Mississippi River,* which he had made with a view of a possible reduction in the number of buckets or of the bucket area. I regret that this portion of his paper was not published. I reproduce his tabulated results here.

Mr. Maltby's summation of his tests was that the bucket arrangement in test No. 3 was untenable on account of the excessive vibration given to the boat, and that, in the last test, the gain in speed of only 0.2 mile per hr. did not justify the increased expenditure of 10 per cent. in h. p. necessary to maintain it. Mr. Maltby's tests were interesting and instructive, and it is to be regretted that further trials were not made with an even reduction of bucket area and with split buckets. The original wheel had 24-in. buckets. These were then increased to 27 in., and finally, from some unknown process of reasoning, the arrangement of 30 in. and 24 in., which Mr. Maltby found in use when he took charge of the boat, was adopted. A varying width of bucket may be made on stern-wheel boats — as is always done on side-wheel boats — to balance the varying direction of pressure and the weights of the cranks and pitmen, but I can see no reason for alternating in even widths.

The number of arms in a 22-ft. diameter wheel, when built according to ship carpenter's rule, would be about 0.8 of the

*Journal Association of Engineering Societies, Vol. xxiv, p. 299, May, 1900.

number of feet in the diameter, or 17; but I know of no steamboat on which this rule has been observed where the vibrations are not uncomfortable to the passenger and also detrimental to the boat and to its speed. Using a formula which presumes one effective bucket to be immersed at all times, and equates the resistance of water per sq. ft. of paddle surface and the mass of water moved multiplied by the distance it is moved, and using the data obtained in the two trials, widths of bucket of 24 in. and of 28.8 in. result respectively, for the 1882 and the 1899 trials. In regard to the number of paddles, 20 in a 22-ft. diameter wheel is large in western river practice, but is frequently exceeded elsewhere. On the *Mississippi*, 4 buckets are more or less submerged at one time, and this number obtains with many boats. On the *Mary Powell*, of the Hudson River, while the buckets are 3.5 in. farther apart than on the *Mississippi*, 6 of them are in the water at one time.

The slip of the most efficient paddle wheel is rarely under 15 per cent. The steamer *New York*, of the Hudson River, is reported to have this slip while running in still water;

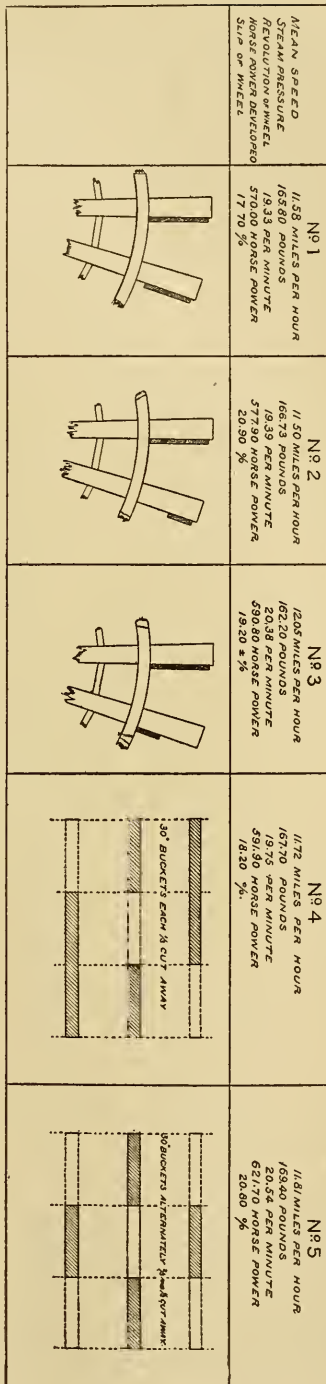


FIG. 12. TESTS OF STEAMER "MISSISSIPPI" AT MEMPHIS, TENN., JANUARY, 1899.

her wheels have feathering paddles. (She will make 24 miles per hr. if pressed.) Fig. 13 shows the paths of the paddles

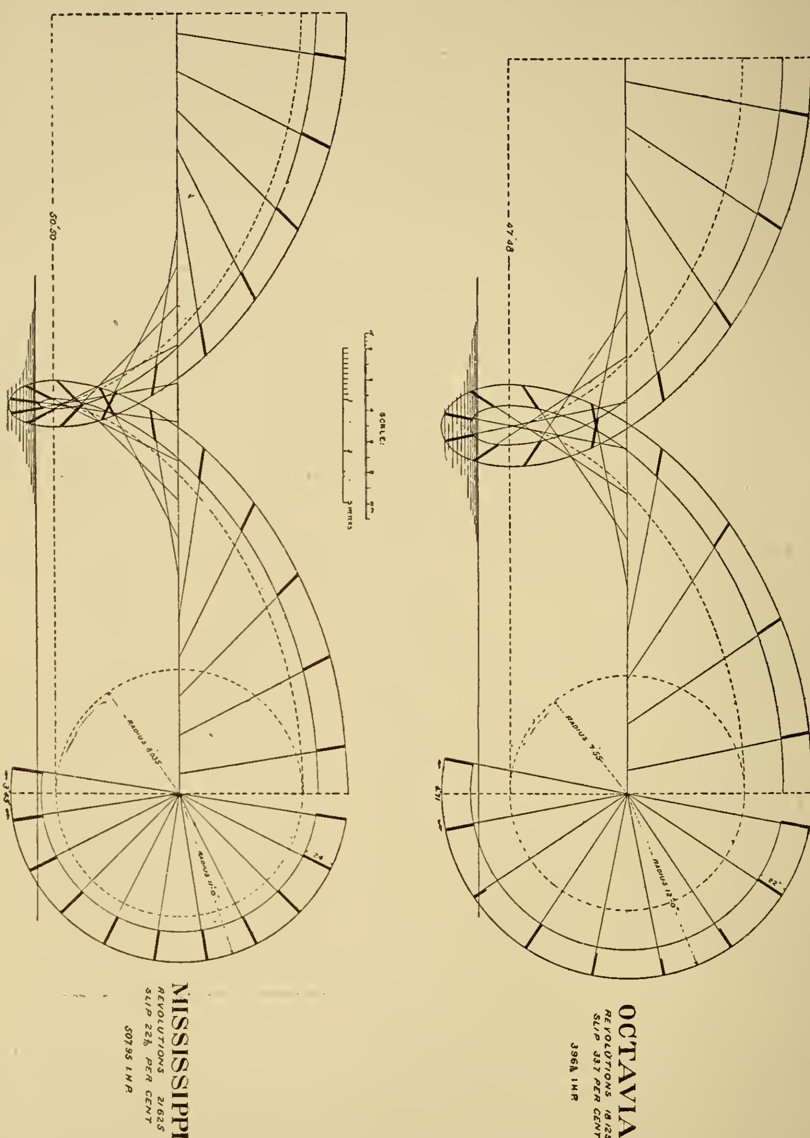


FIG. 13.

during one revolution of the wheel, as observed on the trials of the *Octavia* and the *Mississippi*.

The *Mississippi*, in trial No. 1 of 1899, with buckets alternating 30 in. and 24 in. in width, showed the least percentage of slip, viz., 17.7 per cent. In regard to slip, the best result which has come to my knowledge on western river boats was obtained on the trial of the small iron steamer *Itasca*, built by Allen & Blaisdell in 1881. She has 2 engines, 10 in. diameter by 4 ft. stroke; stern wheel, 12⅔ ft. diameter with 16 buckets 10.75 ft. long by 12 in. wide and making 26.5 revolutions; she gave a mean speed of 9.35 miles per hr. in still water with a slip of 16 per cent.

I do not look for a greater speed for the *Mississippi* in her present condition of rough skin, draft of about 4 ft. and an i.h.p. of 570, than 12.1 miles per hr., which value is obtained from Rankine's formula by giving a value of 0.012 to the frictional coefficient. We have seen that the present wheel of the boat compares favorably with the best practice as regards slip, and, in my judgment, any possible improvement lies in the direction of a uniform width of bucket of 28 in., or possibly of a split bucket, which might permit a slight increase in the piston speed, and not in a reduction in the number of paddles.

To those interested in the financial side of boat building I add a few figures respecting the cost of building the hull of the *Mississippi*. Into the construction of the hull there entered:

219 234 lb. of plate iron, costing delivered	3.54c. per lb.
153 135 lb. of angle and bar, costing delivered	3.64c. per lb.
22 272 lb. of rivets, costing delivered	5.5c. per lb.
5 317 lb. of cast iron, costing delivered	3.03c. per lb.
7 470 lb. of steel shaft, costing delivered	10.7c. per lb.
1 225 lb. of hydraulic tube (rudder stocks), costing delivered	5.2c. per lb.

The cost per lb. for labor was 4.12c., divided as follows:

Mold loft	1.02c.
Machine shop and blacksmith	0.95c.
Fitting	0.91c.
Riveting and calking	0.69c.
Shoring, handling, painting and proportion of yard and shop expenses	0.55c.

The results of the *Octavia's* machinery tests may be regarded as illustrating fair practice, and will compare favorably with many land steam plants, but they, of course, bear no comparison with those obtained from quadruple expansion engines and the higher type of water-tube boilers, where as low as 1.5 lb. of coal per hr. to the i.h.p. has been obtained. There are quite a number

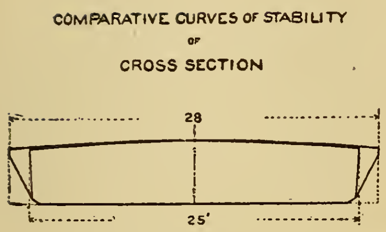
of western river boats, especially on the Ohio River, which have compound engines; they are said to be very efficient, but I am not in possession of any detailed tests of them.

The Missouri River snag-boat *C. R. Suter* (Fig. 14) has compound oscillating engines, which are in every way effective for a side-wheel boat and are particularly adapted for that stream, where rapid action is always necessary, and where, with the ordinary long-stroke engine, the engineer is not infrequently three or four bells behind the pilot's signals. The first cost of these oscillators, of course, largely exceeded that of the common type of engines, and their weights are probably about the same, but we estimate that they save about 100 bu. of coal in a day's run. Taking, however, into consideration the facilities our rivers afford of obtaining cheap fuel at short intervals, the saving of fuel, in which direction recent improvement in machinery has been mostly directed, becomes relatively unimportant when compared to other expenses, and I look for no material change in the type of our boats except in the substitution of well-constructed steel hulls in place of wood.

It may be of interest to the club if I outline the general method of designing a steamboat hull, using an actual case occurring in the practice of the office with which I am connected. The wooden tow-boat *Wm. Stone*, built in 1883, near Pittsburg, was purchased by the United States for the Missouri River improvement. Her dimensions were 136 ft. long by 26 ft. beam by 4 ft. 9 in. depth. In 1892, with steam up and 14 tons of coal on board, she drew 52 in. forward and 34 in. aft, a draft which rendered her almost useless for low-water service. In 1895 she was completely rotted beyond repair, and was wrecked. Her engines were 15½ in. diameter by 7 ft. stroke, driving a wheel 19 ft. diameter, with 14 buckets, 18.25 ft. long by 28 in. wide. It was desired to design for this machinery a steel hull, which, having large cabin capacity, fully outfitted with stores and supplies and carrying about 25 tons of coal in the forward bunker, should have a maximum draft of not over 32 in. Without going into details, a displacement of about 300 tons would be required, and the dimensions of the boat decided on were: Length 147 ft., width of floor about 27 ft. and a central depth of 4.5 ft. In selecting the form of the midship section I was guided by a previous calculation of the relative curves of stability of the two forms shown in Fig. 15. In 1895, when called on to design a new hull for the United States survey steamer *Patrol*, Mr. Ockerson, of the Mississippi River Commission, sug-

Fig. 14. U. S. Snag-boat "C. R. Suter" as Viewed from Above.

Fig. 11.



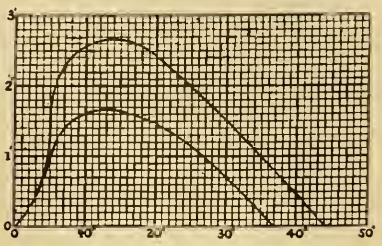


FIG. 15.

gested a wide flaring side without guards in place of the slight flare with guards usual in boats of this type. The abscissæ in the diagram represent the inclination to the vertical in degrees, and the ordinates represent the lengths of the lever arm of the righting moment in feet. The flaring cross-section was adopted for the *Patrol*, and a similar one for the boat under consideration.

In selecting a guiding or main water line, it is my custom to make it a mathematical curve. In the adapted general equation of the parabola

$$\beta = b\left(1 - \frac{y^n}{l^n}\right)^q$$

in which β is any ordinate; b, the half breadth; y, the abscissa, and l, the length of entrance, by varying the power, q, and the exponent, n, any variety of line may be produced. Nystrom, in his "Mechanics," gives a few tables derived from this formula, in very convenient form for use. On the *Patrol* the 2 ft. water line is the curve where $q = 1$ and $n = 3.5$; on the boat being described, $q = 1$ and $n = 2.75$ for the same line, and both are parabolas. When q is greater than 1, the lines become hollow, and are called paracymas. On the *Mississippi* the 2-ft. water line has $q = 1.5$ and $n = 2.375$. The ruling water line and the desired harpin or deck line being obtained, the construction of the other water lines and frame lines of the forward body is the work of the skillful draftsman.

The rake of the stern may be any curve, but I have found it good practice to make the change in direction rather abrupt under water, with a straight line tangent above. All stern-wheel boats have one or more balanced rudders, and when these turn on a vertical axis, in order to preserve a uniform distance from the rake, the forward part of the blade should recess into

the hull. If this is not done, floating drift may find lodgment between the hull and blade and block the rudder. If the rudder turns on an axis at right angles to the rake line, no recess is, of course, required. My drawings show an inclined rudder post for the boat I am considering, but I advocate this arrangement only for small boats, and I shall change the design to vertically-hung rudders.

The diagrams that are to follow illustrate some of the successive steps in the design of the boat. From the drawings of the lines calculations are made, as shown in Fig. 16, of the curves

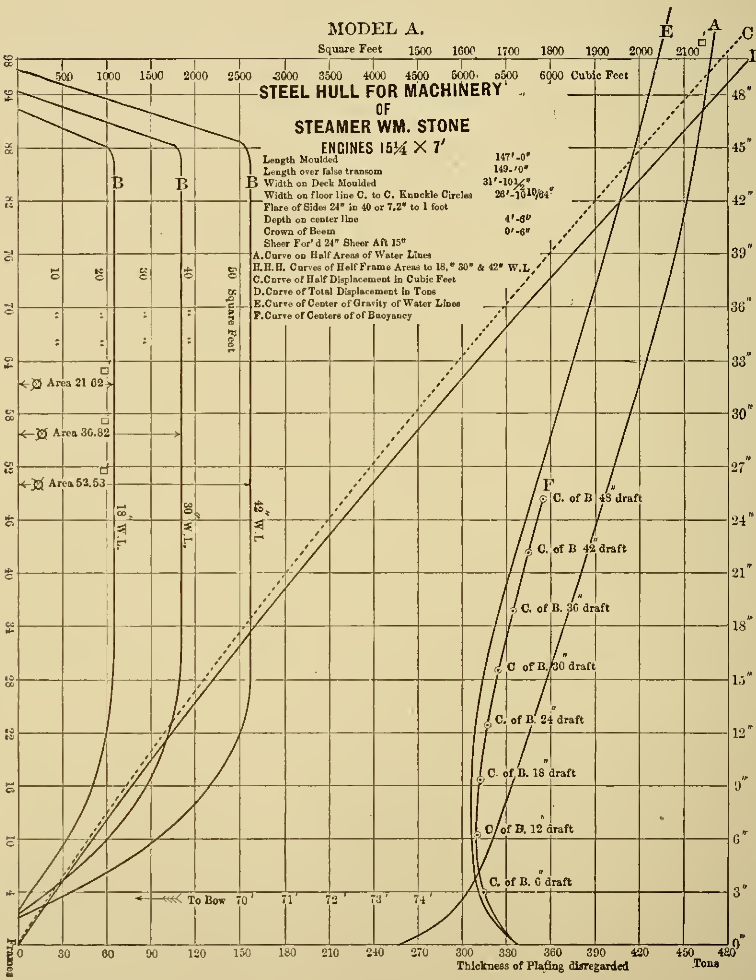


FIG. 16.

of areas of water lines and frames, of displacement, of centers of gravity of water lines and the locus of the centers of buoyancy.

The hull is treated as a girder, the web of which is composed of the fore and aft bulkheads and sides and the longitudinal floors and stringers; and the flanges of the girder are the bottom skin and the deck. The cross frames may be said to serve as stiffening brackets to the girder. At the ends of the hull, for practical reasons, the cross frames are made continuous across the boat, and the longitudinal strength is kept up by longitudinals worked on top of the cross floors. The equivalent girder, though differing in its details bears a general resemblance to that shown in Fig. 10 for the *Mississippi*.

On a stern-wheel boat the location of almost every item above deck is fixed except the boiler group, which at best can be moved a few feet only in either direction. On a merchant boat the freight to be carried is an important factor in the trim, but on a tow boat, if an even draft is desired, the forward lines must be such that the center of buoyancy shall not be brought so far forward that it would require an impracticable weight to bring

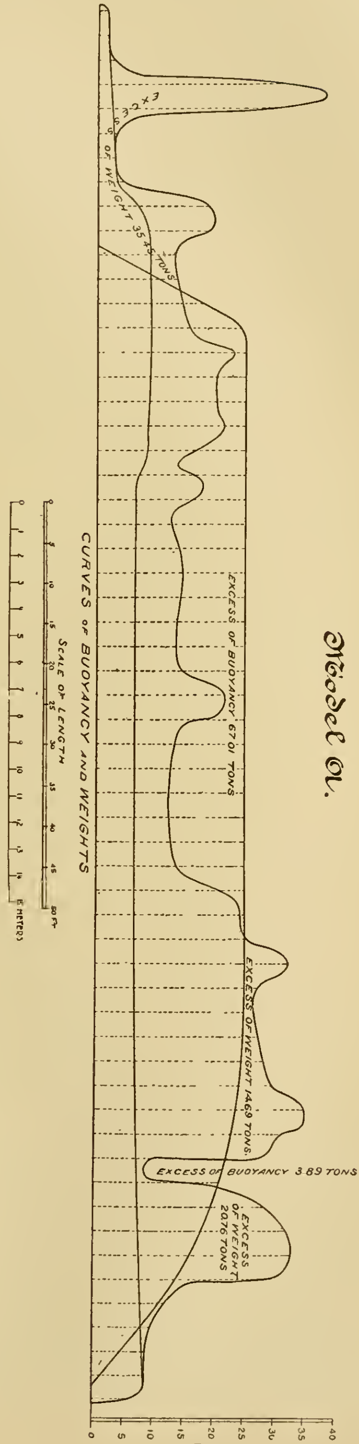


FIG. 17.

the centers of weight and buoyancy into the same vertical line.

The weights of the boat may be approximately stated as follows: Hull, 116 tons; cabin, 40 tons, machinery, 22 tons; wheel. 14 tons; stores and outfit, 30 tons; boilers, 53 tons; coal to make even draft, 25 tons; in all, 300 tons, which, from the scale of displacement, corresponds to an even draft of 32 in.

Further calculations are made for curves of buoyancy and weight, shown in Fig. 17. The upper regular curve is the curve of buoyancy. Each ordinate represents, to scale, the buoyant effort of each foot of length of the hull to a draft of 32 in. The lower regular curve is the curve of weight of the hull alone, and the irregular curve is the curve of weights of the entire boat with its load. The areas of excess in weights and in buoyancy are marked in the figure, and the aggregate of one must, of course, be equal to that of the other. By laying off the differences of the ordinates of the weights and the buoyancy, from a common line, in a plus and minus direction respectively, we have the line shown in Fig. 18, which is called the curve of loads. Here again the areas above the line, representing the buoyancy, must be equal to the areas below the line, representing the weights, and the common center of gravity of all the loops is in the ordinate which contains the centers of gravity of weights and of displacement. The curve of loads shows the manner in which the boat, considered as a beam, is loaded and supported. Between the forward end of the boilers and the coal bin there is a short space over which the buoyancy is greater than the weight, but the main points of support are just aft of the boilers and about 10 ft. forward of the transom.

From the curve of loads we pass by construction to the curve of sheering stresses, which are, of course, maximum at points of support. The point where the stress curve crosses the horizontal line is the point of reverse racking, and this marks the point of the hull on each side of which the boat is separately water-borne; the areas of the curve of .sheering stresses on each side of the racking point must, of course, be equal. From the curve of sheering stresses we pass similarly to the curve of bending moments shown in the regular curve of the figure. The maximum bending moment at the racking point, as scaled, is 1 582.3 ft.-tons. The moment of inertia of the equivalent girder about its neutral axis is 2 558.6; whence, under the conditions considered, the extreme portion of the boat's deck would be subjected to a tension strain of 1.7 tons per sq. in.

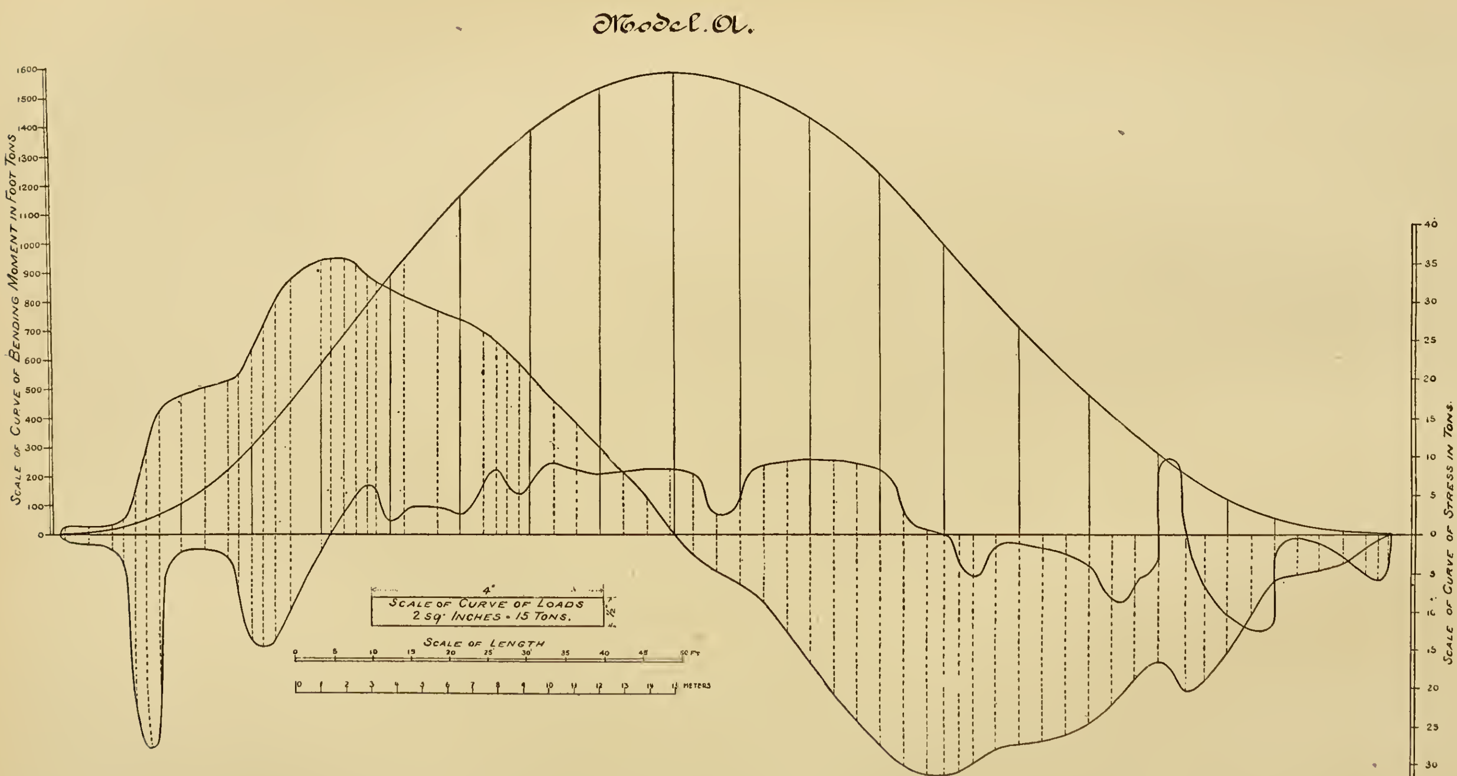

Model VI.
Scale of Curve of Bending Moment in Foot Tons
Scale of Curve of Loads
2 sq. inches = 15 tons.
Scale of Length
Scale of Curve of Stress in Tons.

FIG. 18.

The strains we have considered are, however, those only for the boat lying at rest in still water, and it would be difficult indeed to do more than approximate to the strains to which the boat may be subjected by shocks of grounding when under headway.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by January 15, 1907, for publication in a subsequent number of the JOURNAL.]

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THE DEVELOPMENT OF WOOD BLOCK PAVEMENTS IN THE UNITED STATES.

BY FREDERIC ARNOLD KUMMER, M. AM. SOC. C. E.

[Read before the Boston Society of Civil Engineers, November 21, 1906.]

IN tracing the rather slow development of wood block pavements in the United States it is necessary to deal with a number of stages in this development which did not exist in the evolution of this pavement abroad. It is because of the differences which existed between the development of this class of pavement abroad and in this country that the use of modern wood pavements in the United States has been so greatly retarded.

The English and continental engineers have always been ultra-conservative in the matter of making their constructions of all kinds permanent, while in this country, owing to its very rapid development, forms of construction in all kinds of engineering work have been adopted which were clearly not of a permanent nature, but which, under the circumstances, seemed desirable, if not indeed necessary, for the time being. Therefore, when foreign engineers began to lay pavements of wood, they placed rectilinear blocks upon heavy concrete foundations. In the earlier practice the blocks were not treated at all, and later only insufficiently treated, but owing to the permanence of the concrete foundations placed under them they gave good results from the start, and hence the development of such pavements abroad progressed along smooth and easy lines, involving only such changes as the employment of selected woods, the dipping of the blocks in antiseptic or bituminous compounds and ultimately the treatment of the block by creosoting. Under these

circumstances wood pavements rapidly attained a great popularity, especially in England and France, and the good results which they have given have caused them to become more widely used, especially in those two countries, than any other form of smooth pavement. It is a fact no doubt well known to you all, that most of the streets in London and Paris are paved with wood block laid according to certain established rules which will be mentioned later.

The development of the pavement in the United States has followed widely different lines. Perhaps the first use of wood for road purposes may be found in the corduroy roads built by the pioneers in making their way through the forests. The next development came in sawing the logs so used into short sections 8 to 12 in. long and setting these with the grain vertical upon the earth foundation. Pavements laid in this manner, with the joints and spaces between the round blocks filled with gravel, and in some cases gravel and tar, presented a fairly smooth and uniform surface for travel, and if the character of the timber used was of such a nature that decay took place slowly, such as was found to be the case with cedar and some other woods, this pavement retained a passable surface for a considerable period of time, especially where the sub-grade was of such a nature and so drained that the paving surface did not sink in spots and become irregular. Such a form of construction may appear to us very crude, and from an engineering standpoint in all respects faulty, but with the conditions to be met it was probably the best thing that could be done, since these newly established and poor communities could not possibly have afforded to lay pavements on a concrete base of treated rectilinear blocks, because at that period in the history of this country the expense would have been prohibitive, and the materials for concrete as well as the materials and apparatus for sawing and treating blocks were not available. Pavements of this form were very widely used throughout the country, but in the eastern states, as the prosperity of that section increased, they gradually disappeared. They existed in great quantities in Chicago at the time of the great fire and are still laid in many sections of the western part of the United States. As a sort of a side issue from this form of construction, and because of certain peculiar conditions, pavements of round sawed blocks on a concrete base are still being laid in some parts of the United States. In Detroit, for instance, it becomes necessary for the property owners to lay the first pavement on a street, after which the repaving is done by the

city at large. On many streets of this character round cedar blocks are placed on a concrete base because of their cheapness. I understand that they are laid for about 50 cents a square yard. They give a fairly serviceable pavement for about five years, after which the city places on the existing concrete base some suitable and more expensive smooth pavement. The use of blocks in this way is, however, an off-shoot from the steady development of the wood block idea throughout the country. After the gradual disappearance throughout the east of the old cedar and other round block, wood pavements were not heard of to any great extent for a considerable period. Shortly after the Civil War efforts were made to introduce a rectilinear wooden block under a system generally known as the Nicholson pavement. For this form of construction there was no excuse, and the fact that it was laid to an enormous extent throughout the country is not a great credit to the intelligence of our engineers at that period. The Nicholson pavement was laid as follows: The surface of the roadway was shaped up to crown and grade, but was usually not rolled and therefore was not sufficiently unyielding to permit of the laying of a block pavement upon it. To overcome this difficulty promoters of the Nicholson pavement placed a layer of wooden planks 1 in. thick over the surface of the roadway. These planks were not treated in any way, and it should have been evident to any one that they would rapidly rot out. The blocks placed upon this foundation were of various woods, whatever happened to be the most convenient at hand, and were merely short sections of timber sawed from the ends of planks of varying width, dipped in hot tar and set in place, with intervals of from $\frac{1}{4}$ to $\frac{1}{2}$ of an inch between the blocks, these intervals or joints being filled with tar and gravel. When first laid they presented a smooth and uniform surface to drive over and obtained a great deal of popularity. In the course of two or three years they failed completely because of the rotting of the blocks and the rotting and sinking of the plank foundation. Enormous quantities were used in most of our eastern cities. Elizabeth, N. J., is still paying interest on bonds for improvements of this character. Almost all the streets in Washington, D. C., were paved in this manner, and only about two years ago the writer came across a section of this pavement in Brooklyn where an asphalt pavement had been laid over the top of the old Nicholson block. The asphalt was being removed and the block and planking, most of which were completely rotted away, had been exposed.

It is doubtful if any form of pavement construction could have been devised which contained more faults and fewer merits than this Nicholson pavement. From the ground up it had not one feature to recommend it. The loose and uncompacted character of the foundation was against it, the use of the planking as a foundation inevitably meant rot and failure, the dipping of the block in hot tar was the worst thing that could possibly have been done and was the surest method of making decay as rapid as possible, and the laying of the block with an open joint served only to admit water and cause the under-planking to rot more rapidly than it otherwise would have done. It is possible that the statement just made regarding the dipping of the blocks in tar may not be completely understood. The fact is, that these blocks were very largely of green timber, full of sap, and as soon as the blocks were dipped in the mixture of hot tar, the pores of the wood were sealed up and the escape of this sap and moisture in the wood prevented. The immediate result was the fermentation of the sap with resulting dry rot. Most of the block collapsed like punk inside of three or four years. Had this pavement been laid without dipping the blocks in tar, they could have seasoned to some extent in place and would have had only the failure of the foundation to contend with, or had the blocks been seasoned by air drying for a period of a year before being laid and then dipped in hot tar, their life would have been considerably greater. As I have stated above, the use of this pavement in such enormous quantities was not a credit to American engineers. The theory of creosoting and preservation of wood was well understood in England and on the Continent at this time, and it should have been evident to any one that the results which followed the use of this pavement were inevitable.

Shortly after such an experience with wood pavements there began an eager search for some form of construction which would give smooth pavements which were at the same time durable, and about this time asphalt pavements were introduced into the United States and the use of wood almost entirely disappeared. This was the condition which existed in the United States about twelve years ago, when the use of creosoted wooden blocks on a concrete foundation was again taken up. Prior to this time some small sections of this pavement had been laid, notably in Galveston and New Orleans, where facilities for creosoting the blocks existed. The attention of the authorities of Indianapolis, Ind., was called to the results which this pavement had given, through the existence in Indianapolis of a small

creosoting works, and blocks treated with small quantities of creosote oil were laid in some streets on concrete foundations. This use of blocks of this character marks almost the beginning of the intelligent use of wood pavements in this country. In the period which has elapsed since then, the popularity of the pavement has grown enormously, and it is estimated that 1 500 000 sq. yd. were laid during the past year.

The writer first became interested in the subject of pavements of this character about seven years ago. A thorough canvass of the condition of the art at that time indicated that four important elements entered into the construction of a first-class pavement of this character. These elements are as follows: First, the foundation. Second, the character of the wood employed. Third, the character and amount of the treatment. Fourth, the method of laying the block.

Naturally, in any attempt to lay pavements of this character, a careful study of what had been done up to date was necessary. It was found that abroad foundations were almost uniformly of Portland cement, ranging in depth from 6 to 8 in., although in some cases heavier foundations were used. With the exception of reducing the depth of the foundation to from 4 to 6 in., depending upon the character of the sub-foundation and the nature of the traffic, no improvement seemed possible in the construction of this part of the pavement.

With reference to the character of the wood employed, it was found that abroad certain hard woods from Australia, known as karri and jarrah woods, were used to considerable extent untreated, while considerably softer woods, such as Norway pine and native French pines, were employed untreated, or merely dipped in hot creosote oil or boiled in same, or treated under pressure with from 8 to 10 lb. of oil per cu. ft. It was felt that the Australian woods untreated would be subject to decay, although these woods are of such character that they decay much less rapidly than most varieties of timber. Their use in England is not now as great as it formerly was. They are used to a very small extent in France and are not liked in Germany, although an Australian wood known as tallow wood is used to a limited extent. At the same time, it was felt that the soft deals and woods of the pine family were not sufficiently rigid and had not sufficient resistance to abrasion to make them entirely suitable for heavy travel. About this time enormous quantities of southern pine, known as long-leaf or Georgia pine, began to come into the eastern market, owing to the rapid cutting out of

the white pine forests of Michigan and throughout that territory, and in this wood, owing both to its plentiful supply and its toughness and hardness and adaptability for the reception of creosote oil, there existed an ideal wood for the manufacture of paving blocks. It was determined, however, that blocks of this character must be made of the heart of the tree only, as the sap wood, being much softer than the heart, would tend to wear away more rapidly and produce uneven wear on the surface of the pavement. At that time all-heart long-leaf yellow pine was readily obtainable in large quantities at prices about $10 per 1 000 less than would now have to be paid for similar lumber containing quite a high percentage of sap. The all-heart lumber, owing to the great demand for this character of material, is out of the market except at prohibitive prices.

Coming to the question of the nature and amount of treatment to be employed, it was found that owing to the absorption of water many of the streets laid in the early history of the business, treated with 8 or 10 lb. of straight creosote oil to the cubic foot, absorbed considerable quantities of water, resulting in swelling up after heavy rains, buckled so that the surface was destroyed, and often these pavements got into a dangerous condition. To remedy this difficulty it was determined in the first place that the block must be as completely filled with preservative material as it would permit; that is, all the pores of each individual block should be thoroughly filled with the oil. It was also felt that ordinary straight creosote oil, the dead oil of coal tar of commerce, was not sufficiently waterproof to properly exclude moisture from the block; and to overcome this difficulty melted rosin was introduced along with the oil, the two materials making a perfect mixture, which not only impregnated all parts of the block, but sealed up the pores so that moisture was excluded and the fiber of the wood stiffened and rendered better able to resist impact and abrasions. The proportion of rosin used at first was from 50 to 60 per cent., but the general practice at the present time is to use about 25 per cent., the reduction in the amount of rosin being made possible by improving the quality of the oil used. Some of the lighter creosote oils are of such a low specific gravity that they require 50 per cent. of rosin to render them sufficiently dense to thoroughly seal up the pores of the wood and prevent the entrance of water; but by specifying oils of very high boiling points, very heavy and dense and non-volatile oils may be secured which do not require such a high percentage of rosin. This change does not in any

way impair the value of the treatment, and at the same time prevents the cost of the block from running to a prohibitive figure, owing to the fact that rosin has advanced several hundred per cent. in value during the past few years, and at its present value, if 50 per cent. of it were used, the cost of the pavement would be needlessly increased. Inasmuch as wood pavements are already high in first cost, any unnecessary increase in their cost would operate to decrease their use by municipal authorities.

Coming to the question of the method of laying, it was found that the almost universal practice abroad was to lay the blocks with a joint between them of from about $\frac{1}{4}$ to $\frac{1}{2}$ of an inch in width, this joint being secured by putting small separating lugs on the sides of the blocks, or more generally by using wooden strips between the courses, these strips being afterwards removed and the joints filled with gravel and coal tar or pitch. This method is still widely used abroad, especially with the untreated or Australian woods, although with treated blocks the practice of laying the pavement with tight joints is now coming into favor. The idea of the wide joint was twofold. *First*, to render the very hard and slippery surface of the Australian hard woods less slippery by providing grooves across the street, and *second*, to allow room for expansion in case the blocks absorbed water. This second purpose was never fulfilled by a wide joint, and it seems strange that engineers could have ever supposed it would be. The reason is as follows: If the joint is packed tight with gravel and tar and the usual dirt existing on the surface of the street, it becomes practically as solid as the block, and if the blocks expand, the joint has no elasticity, and consequently the expansion is not taken up and acts in the same way as if the joint were tight. Furthermore, with wide joints there is a much greater chance of expansion than with tight joints, as it presents an opening for the water to soak through the pavement and lie on top of the concrete and be gradually absorbed by the block, whereas with tight joints the water, instead of getting under the block, runs off to the gutters. The writer has always believed that it is better to prevent expansion by so treating the blocks that they will absorb the minimum amount of water rather than by providing means to take it up after it occurs. It is still necessary, however, under certain conditions, to use an expansion joint.

Working out the problem along these lines, it was determined to lay blocks as thoroughly treated as possible, with perfectly tight joints, using only very clean fine sand to fill up any

crevices in the pavement surface which might exist. It was also thought best, in conformity with the usual English practice, to lay the blocks at right angles to the curb line except at intersections.

The first wood pavements laid in the East were laid on a sand cushion, as is the case with brick and stone. These pavements require a sand cushion, as they are not elastic enough to be set upon a rigid concrete base, but wood blocks, being in themselves elastic, are better laid upon a rigid foundation without the use of a sand cushion. This, of course, requires the block to be all cut to a uniform depth, but when laid in this way there is no danger of the cushion shifting, and also if any water gets through the surface of the pavement it does not have an opportunity to collect in the sand cushion and be absorbed by capillary attraction into the block. It is most essential in the case of wood pavements, perhaps more so than in the case of any other form of pavement, that the surface be kept uniform. The English practice is to float the surface of the concrete with a mortar, which mortar is allowed to become hard and smooth like the surface of a granolithic sidewalk, before the blocks are laid, and in many cases this mortar surface is covered with a layer of hot pitch in which the blocks are set. I am inclined to believe that this is a very excellent form of construction, probably better, although somewhat more expensive, than that now generally employed in this country. The usual method here is to true up the surface of the concrete in the same way with a mortar bed, but this bed is mixed damp instead of wet, and the blocks are laid in it before it has set and then tamped with an asphalt rammer until the surface is smooth and even. A certain amount of the mortar is squeezed up between the joints at the bottom of the block and closes this joint so that water cannot work its way under the block.

The English blocks are almost uniformly 3 in. wide, 9 in. long, running as high in depth as 6 in. It was felt that soft pine blocks of this depth would wear much more rapidly than blocks of Georgia pine, heavily treated, and it was concluded that 4 in. was amply deep for the heaviest travel. The first blocks were made 4 in. wide, 8 in. long, instead of 9 in., it being somewhat easier to get all-heart yellow pine planks of the smaller width. They were also cut 4 in. deep, but it was found that there was a constant tendency on the part of the workmen to lay them with the grain the wrong way, the dimensions as to width and depth being the same. The width of the block was therefore changed, some three or four years ago, to 3 in., making a standard block

Tremont Street, Boston, from Park Street.

A Roadway of Williamsburg Bridge, New York City.

3 in. wide, 8 in. long and 4 in. deep. Experience with blocks of the character of timber and treatment mentioned above on one of your principal streets, Tremont Street, has shown the rate of wear to be so small after six years that I believe that the blocks $3\frac{1}{2}$ in. deep, now used almost universally as a standard throughout the East, are amply heavy provided the character of the timber used and the quality of the treatment are maintained.

Still another modification in the size of the blocks has been introduced in some of our largest cities. The increasing scarcity of available timber for manufacturing blocks has rendered it more and more difficult to get blocks 8 in. long of the quality desired, and it has been thought that the pavement would not in any way suffer if blocks of random lengths from 6 to 10 in. were employed, but in laying these blocks care must be taken that the joints are properly broken.

Coming to the question of the joints between the blocks, in my opinion nothing is superior to clean fine sand, used either very dry or hot and thoroughly swept into the joints; but unless the sand is of especially good quality — clean, very fine and dry — a cement grout joint will give better results. The sand joint, however, can only be employed on streets of considerable travel, where the action of the traffic can be depended upon to expand the head of the blocks sufficiently to practically close up the joints. On streets of light travel this action does not take place, the blocks sometimes get loose and absorb water, and, no matter how thoroughly they are treated, the accumulation of a very small expansion in each block over a considerable distance may produce some disturbance of the pavement. On light traveled streets some form of pitch joint is desirable. If hot paving cement is spread carefully over the surface of the street and swept into the joints with a squeegee, and the surface then quickly covered while the pitch is hot with a layer of sand or fine screenings, good results will be secured, but experience has shown that it is almost impossible to use pitch in this way in cold weather. Most of it remains on the surface of the pavement and later, when the weather gets warm, this becomes so sticky and disagreeable that much annoyance is caused to pedestrians and property owners. It is possible to pour the joints from a can, but unless this work is very carefully done most of the pitch will still be on the surface of the block. The company with which the writer is connected is now paving some streets in Baltimore, Md., where the surface of the streets is swept with hot pitch, as above described, on which is placed fine granite screenings, after the

English practice, the idea being that these screenings will be crushed into the joints and into the surface of the blocks by travel, tending to reduce any slipperiness which may exist on these streets. The streets in question have sufficient grade to render them a little slippery in wet weather.

It will be seen from the above that there are no very vital differences between the methods of laying wood block in this country and abroad, although it should always be remembered that the English and continental practice is to use very much less oil in the block than is used in this country, 10 lb. to the cubic foot being a maximum, as against 20 to 22 here. The English engineers have been approaching the American practice by using tight joints and shallower blocks, 4-in. blocks being used very largely there now, while formerly 5- or 6-in. blocks were being used, while the American engineers, by adopting the mortar bed and the use of granite screenings on the surface of the pavement instead of sand, are on their side approaching the English practice.

The above résumé of some of the lines along which wood block pavements have progressed does not, of course, cover all of the questions which have come up from time to time. One of the most important of these is the kind of timber to be employed for the blocks. All-heart long-leaf yellow pine seemed at one time to be the ideal wood for this class of work, but the rapid increase in the use of pine in all classes of construction work, and the diminution of the supply, have raised the price of timber of this character to a point where it cannot be used in large quantities for the manufacture of paving blocks except at very high prices. Naturally this condition has resulted in an effort on the part of wood block manufacturers to find other woods than pine which will fulfill the requirements for the manufacture of paving blocks. Tests are being made on a number of woods, such as Norway pine and tamarack in the northwest, and other tests are proposed, embracing short-leaf pine, loblolly pine, beech, maple, scrub pine and scrub oak. Of all the woods which have been considered, the black gum of the South seems to promise the best results. This is the wood which is now being laid on Washington Street in your city. It is a very tough, hard wood, with an irregular grain, and if used in the shape of planks is badly subject to warping. Used in the shape of blocks it seems to have no disadvantages and many advantages over other woods, even over pine in some respects. It is, of course, a swamp wood and, untreated, decays rapidly, but when thoroughly treated with a

creosote oil mixture it resists decay perfectly, and the experience of somewhat over a year of very heavy travel in New York City has shown that it wears remarkably well; in the opinion of some, even better than pine. On account of its close and irregular grain it does not split as readily as pine and the waste in handling on the street is less. It exists in large quantities in the South, and inasmuch as it is not very useful for general lumber purposes the chances of getting it in large quantities at reasonable prices for a considerable period are good. Some 75 000 sq. yd. of this paving material have been manufactured and laid under the writer's supervision during the past year, and all of it is giving excellent results.

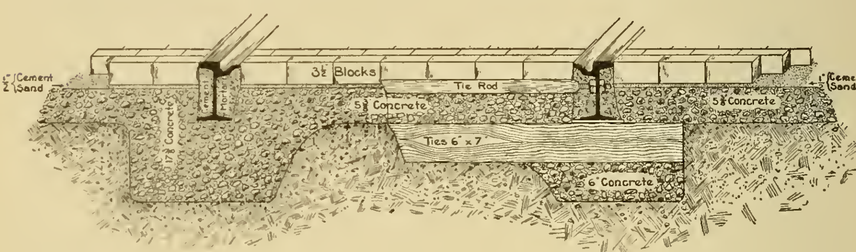
The perfect wood pavement would be one laid on a well-drained and compacted foundation, upon which is placed a suitable concrete base of such depth as to properly carry and distribute the loads which pass over the street, and having its upper surface brought to perfect crown and grade by the use of cement mortar, with blocks set in same while damp, or set upon same after hardening, in a coating of hot pitch, with all the blocks of a dense, tough and homogeneous wood, the pores of which are entirely filled with an antiseptic and waterproof mixture to exclude water. It should be laid with the blocks driven as tightly together as possible, and the joints filled with clean fine sand, cement grout or pitch, according to circumstances, all the blocks being cut to exactly uniform depth so that the surface of the street is perfectly even. Such a pavement, if not cut to pieces by public-service corporations and by trenches for sewer and water pipes, should give, under the heaviest travel, a life of from ten to fifteen years, with a rapidly increasing life as the character and amount of the travel becomes less destructive. It has been our effort to arrive at these conditions, and it should be a source of satisfaction to American engineers that the city engineer of one of the largest cities in the United States, after spending three months abroad last summer, devoting his entire time to the study of foreign pavements, should have reported upon his return that he saw no wood pavements anywhere abroad which were superior to those laid in his own city.

DISCUSSION.

Mr. Arthur L. Plimpton. — As, at the time of the excursion to-day to Washington Street, Boston, the track work was covered up, I thought it would be of interest to show just what the construction was, and I had this cross-section prepared.

You will note that the rails are supported on the usual tie construction, ties being 2.5 ft. on centers, which in turn are supported in and on a continuous concrete beam extending 6 in. below the bottom of the ties, and about 5.5 in. above them, giving a total thickness of about 17.5 in. These beams are connected by an arch of concrete, which gives about 5.5 in. of concrete base in the middle for the wooden block pavement.

Previous experience on Beacon Street, where wooden blocks were laid in 1901, showed the importance of doing the work in such manner as to prevent water from working down at the side of the rail, which, when followed by freezing weather, will cause the blocks to heave up. In laying the tracks on Washington Street, therefore, it was decided to plaster with cement mortar next the rail its entire height just before putting in the concrete, which insured intimate contact between the concrete



WASHINGTON STREET, BOSTON ELEVATED RY., SURFACE LINES.

and the rail, so that when done there were no voids left in which water could accumulate. In the work recently done of relaying the tracks on Beacon Street with wooden block pavement the blocks themselves were laid on a layer of cement mortar and the joints filled with cement grout.

Cars were not run on the tracks on either Washington or Beacon Street until the concrete had been in place for ten days.

The whole aim in this form of track construction is to eliminate all movement of the rail under passing cars as far as possible, and in some recent work in connection with brick pavement a form of screw has been used instead of the usual track spike which, with its vastly greater holding power, will certainly help a great deal to prevent movement of the rails; and if the results justify the added cost, it will probably be adopted instead of the spike in future work in connection with expensive forms of pavement.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by February 1, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Charles Paine.

HONORARY MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

CHARLES PAINE, veteran railroad manager, born in New Hampshire, 1830, died at Tenafly, N. J., July, 1906. This interval of life, prolonged beyond the usual span, represents a busy, well-rounded career of railroad service.

He began as a youth of fifteen on the Vermont Central Railroad, and at seventy we find him assuming the duties of general manager of the Panama railroad. In 1858 he became a superintendent of the Michigan Southern and Northern Indiana lines, and in 1864, chief engineer. In 1872 he became general superintendent of the Lake Shore and Michigan Southern Railroad.

It was during the twenty-three years of his connection with the Lake Shore properties that he established a wide reputation as an administrative officer of exceptional ability. He left Cleveland in 1881 to take charge of the construction of the New York, West Shore & Buffalo Railroad, and remained there until after its completion in 1884, when he spent a year studying railroads in Europe. He was for a year second vice-president of the Erie, and then accepted the vice-presidency of the Philadelphia Company, which owned the natural gas properties around Pittsburg, and he held that position five years. The years 1891 to 1899 were devoted to private practice as a consulting engineer. In 1899 he was made general manager of the Panama railroad. He was a past president of the American Society of Civil Engineers, an honorary member of the Western Society of Engineers and of the Civil Engineers' Club of Cleveland, and a member of the American Society of Mechanical Engineers and of the Century Club of New York.

Although his later years were largely occupied by administrative duties, he never forgot his engineering training, and as leisure permitted wrote freely on railroad subjects. The viewpoint was that of a veteran engineer, and the series of papers which were later incorporated into his popular book, "The Elements of Railroading," were not only instructive, but written in an easy and entertaining style.

Mr. Paine was a successful administrator of railroad properties. He was trusted by his capitalists, maintained discipline and efficiency without provoking antagonism, and was diplomatic in his attitude toward the public. Like many men of

large affairs, he was not averse, on occasion, to looking after details. An instance in point of his thoroughness is related by Mr. Burgess, who says that at one time he went down the line with Mr. Paine. Upon crossing a track the latter made the remark, "I never step on to a track but that I immediately step off again. A simple thing, but I know of some poor fellows who, if they had followed this rule, might be alive to-day."

He resided in Cleveland many years, and, when the matter of forming an engineers' club was first considered, one of the serious problems was to select a suitable president. It was a most fortunate circumstance that the name of Charles Paine was suggested and found instant favor. The only drawback was the fear that it would be regarded as something of a presumption to ask him to take it, especially as the club was making a very modest beginning. No sooner, however, were our purposes made known to him than he entered into the project with a heartiness and enthusiasm that was as gratifying as unexpected. It was no perfunctory acceptance, but was cheerful and gracious, and ever after during his short remaining residence in the city he made it his business not merely to be our leader, but to be for us and to be one of us. The first formal meeting was held March 13, 1880. There had been misgiving and doubt as to what the movement might amount to, when the engineers of Cleveland, many of them utter strangers to each other, met in a body for the first time. When, however, Mr. Paine took the chair and in a dignified address gave eloquent expression of the dignity and importance of our calling, we began to realize that something might be accomplished by better acquaintance and concentration, and no one present then, or at subsequent meetings over which he presided, will forget the real interest he took in the work of the club, or the singular charm of his presence and manner. We felt that he had a genuine interest in every engineer, every young one especially.

We have appreciated and have felt an interest in his wide fame, in the many high positions he has filled with ability, grace and honor. We feel it a duty and a privilege to testify that when this society had its beginning, it was favored with his useful and kindly services and the impetus of his name.

WALTER P. RICE,
C. H. BURGESS,
HOSEA PAUL,
Committee.

Editors reprinting articles from this JOURNAL are requested to credit the author, the JOURNAL OF THE ASSOCIATION, and the Society before which such articles were read.

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A STUDY OF THE EFFECT OF NEW ORLEANS CANAL WATERS ON CRAB LIFE.

BY R. M. REDDING.

[Read before the Louisiana Engineering Society, October 8, 1906.]*

LAST summer I sought an explanation for the abnormal mortality among the fish and crabs of Lake Pontchartrain. Believing this question of some general interest, I wish to present to you to-night the results of this study.

In as much as I was interested only in finding the cause of this abnormal mortality, I did not make an exhaustive examination along every line, but confined my study of the various canals to the possible and probable waste products emptying into that particular canal. In following out this line I examined each canal emptying into the lake for free acids and alkalies, phenols, cresols, naphthols and other tar products, sulphates, chlorides, and other probable mineral salts. The result of this line of work, covering some weeks, was *nil*, so I shall go into no detail on this line.

Since no deleterious substance of a mineral nature was detected in quantities to affect, it was an evident conclusion that the death of the crabs was due to some other cause. This belief was strengthened by the fact that the canals receiving the most waste from factory sources were not the most destructive to crab life. Further, that the two most destructive, Bayou Lauria and Seventeenth Street, are several miles apart, the former receiving little, if any, sewage.

The second line of study which I took up was suggested by the peculiar action of crabs in the canals. Agitation, increased

* Also read before the Louisiana Chemical Society.

respiration, attempts to remain at the surface and desire to get out of the water, led me to think that perhaps the water lacked oxygen.

As part of the evidence on which I shall later draw my conclusion, I wish to quote from S. Rideal ("Sewage and Bacterial Purification of Sewage"), showing the chemical process and steps in the oxidation of organic matter in sewage. "The oxidation of organic matter under favorable conditions of temperature has four stages, as shown in the accompanying table, the initial change occurring rapidly, using up the free oxygen in the water, after which the succeeding changes take place more slowly through the agency of enzymes."

ORDER OF CHANGE.

	Substance Dealt With.	Characteristic Product.
Initial.		
Transient aërobic changes by free oxygen in water, rapidly passing.	Urea, NH_3 and other easily decomposable bodies.	
First Stage.		
Anaërobic liquefaction and hydrolytic changes.	Albuminous matter, cellulose and fiber, fats.	Soluble nitrogenous compounds, phenol derivatives, gases, NH_3.
Second Stage.		
Semi-anaërobic; breaking down of the intermediate dissolved bodies.	Amido compounds, fatty acids, dissolved residues, phenolic bodies.	NH_3, nitrites, gases.
Third Stage.		
Complete aëration and nitrification.	NH_3, and carbonaceous residues.	CO_2, H_2O and nitrates.

Also from J. H. Long (Journ. Am. Chem. Soc., January, 1890).

Long studied the oxidation of highly charged waters in the Illinois River for a distance of 160 miles. He found that the water rapidly lost its free oxygen, and that nitrates as indicative of the final stages of oxidation did not appear for many miles.

That sewage does not quickly pass through the intermediate stages to the point of re-aëration was demonstrated by Fowler, of Manchester, England.

He experimented on chemically precipitated sewage and got results as follows:

Where Air Passed over Surface. Hours Exposed.	Oxygen-Consuming Power per Liter in Grams.	Air Drawn through Liquid. Hours Exposed.	Oxygen-Consuming Power per Liter in Grams.
0	2.52	0	2.00
21	2.58	4	2.08
27	2.57	6	2.00
72	1.44	23	1.62
95	1.26	27	1.50
100	1.21	47	1.31
117	1.16	51	1.20
141	0.80	71	0.90
		95	0.51

The work of these men demonstrated that water heavily contaminated is in a more or less oxygen-free state, and remains so until the stage of re-aëration is reached, unless greatly diluted with oxygen-carrying water.

With these facts in mind I wish now to give you the conditions found existing in the canals of New Orleans.

In presenting the results of these examinations I have used two standards — aërated distilled water and Lake Pontchartrain water.

	Cu. Cm. per Liter.
Aërated water, distilled, at 86 degrees fahr:	
Dissolved oxygen	5.42
Required oxygen	0.00
(Dissolved oxygen at 86 degrees, according to Roscoe and Lunt, 5.43)	
Lake Pontchartrain:	
Sample taken July 5, 1905, one mile off Southern Yacht Club.	
Dissolved oxygen	4.38
Required oxygen	3.40
(Leed's standard for American river waters is 3.5 cu. cm. to 4.7 cu. cm.)	
Orleans Canal:	
Sample taken July 12, 1905.	
Conditions: Weather settled. Canal carrying average sewage.	
Dissolved oxygen	2.94
Required oxygen	13.63
Seventeenth Street (Bucktown):	
Sample taken July 7, 1905.	
Condition: Water heavily charged. Much evolution of gas. No evidence of crabs or fish. Crabs killed in cars in this canal in morning of this date. Dead crabs in evidence.	
Dissolved oxygen	1.94
Required oxygen	12.00

	Cu. Cm. per Liter.
Bayou Lauria:	
Sample taken July 12, 1905.	
Condition: Water almost black with suspended matter. Free bubbling of gases. Much evidence of dead crabs and fish.	
Dissolved oxygen	0.00
Required oxygen	16.24
Broad Street Canal:	
Sample taken July 14, 1905.	
Condition: Fair. Water low in canal.	
Dissolved oxygen	1.15
Required oxygen	32.33
Gutter Water:	
Sample taken July 14, 1905.	
Condition: Bad. Heavily charged with organic matter.	
Dissolved oxygen	0.00
Required oxygen	63.70
Water from St. Louis Pumping Station:	
Sample taken July 24, 1905.	
Condition: Bad. Water at temperature 97 degrees fahr. Much organic matter and excessive evolution of gas.	
Dissolved oxygen	0.00
Required oxygen	46.88

On July 25 I collected a sample of gas from this canal and analyzed same.

ANALYSIS.

	Per Cent.
CO_2, etc.	1.20
CH_4	88.92
H	0.00
N	9.88
	100.00

	Dissolved Oxygen.			Required Oxygen.	
	Cu. Cm. per Liter.	Per Cent. of Aërated Distilled Water Value.	Per Cent. of Lake Water Value.	Cu. Cm. per Liter.	Per Cent. of Lake Water Value.
Aërated distilled water	5.42	100.00	123.74	.....	.....
Lake Pontchartrain	4.38	80.81	100.00	3.40	100.0
Orleans	2.94	54.24	67.12	13.63	400.9
Seventeenth Street	1.94	35.79	44.29	12.00	352.9
Bayou Lauria	0.00	....	....	16.24	477.6
Gutter water: Perdido and S. Howard	0.00	....	....	63.70	1 873.5
St. Louis Pump. Station	0.00	....	....	46.88	1 378.9
Broad Street Canal	1.15	21.25	26.25	32.33	950.9

In considering the above it should be borne in mind that these values are much in favor of the canals, since the samples tested were taken in a period of settled weather, and also within 15 in. of the surface, where aëration is greatest.

Yet under these favorable conditions, Seventeenth Street Canal represents a state in which crabs had died a few minutes previous to the taking of the sample of water. By testimony of fishermen the greatest mortality among the crabs is shortly after heavy rains, when the city refuse is swept down the canals. Mortality among the crabs caught by this rush is nearly 100 per cent.

This is what one would expect, since the sweep of the city sewage in large volumes fills the canals with sewage in the first and second states of decomposition, the state in which little free oxygen is found in the water.

Not satisfied with drawing a conclusion untested, I took a good clear water, expelled the air by boiling, allowed it to cool out of contact with air, and made up dilutions of various percentages of aëration. Using a vessel of about 12 or 15 liters capacity, with an arrangement for excluding air from the surface, I placed strong, vigorous crabs in different samples of partially aërated water with the following results:

In each case the crab showed immediate signs of distress, rapidly increasing respiration, with respiratory organs open to the limit and circulation of water increased by means of every appendage of the head and fore part of body.

A. In dilution of 20.81 per cent. normal, the first crab died in 40 min., the second in 45 min. Per cent. of normal aëration at end, 13.0 per cent.

B. In dilution of 18.40 per cent. normal, first crab died in 25 min., second in 100 min.

C. In dilution of 33.21 per cent., crab died in 35 min. Per cent. of normal aëration at end, 20.5 per cent.

D. In dilution of 38.47 per cent. normal aëration, crab died in 40 min. Per cent. of aëration at end, 33.10 per cent. normal.

In no case did a crab survive longer than 100 min., the average being 47.5 min.

Rideal, Long and Fowler demonstrated that heavily charged water undergoing purification contains but little free oxygen, and remains in this condition until the point of re-aëration is reached. The time required for this point to be reached is much greater than that required for sewage to travel from the city to the lake. Long followed the Illinois for a distance of 160 miles, and,

although the water was constantly being diluted, found the evidence of final stages only far down the river.

The conclusion logically follows that the death of the crabs is not due to poison directly injected into the canals, but is due to the absence of free oxygen in the water, assisted possibly by the presence of intermediate products of oxidation of organic matter. These conditions are brought about by the water in the gutters and canals being heavily charged with organic matter, which standing stagnant for days in the hot sun undergoes decomposition of organic matter, thereby denuding the water of its free oxygen.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by February 15, 1907, for publication in a subsequent number of the JOURNAL.]

IRRIGATION WORKS IN ARIZONA.

By C. L. Gates, Member of the Toledo Society of Engineers.

[Read before Society, April 13, 1906.]

The general subject of "reclamation," or reclaiming for agriculture ordinary arid lands by irrigation, a part of which subject this paper treats, may present but little interest to an audience in Ohio, but to the farmer or range man and resident of the great West and Southwest it is of vital importance; in fact, upon successful irrigation in that region depend the farmer's and stockman's very life and existence.

It was recently my fortune to travel through Arizona, that "land of promise and fulfillment," a very appropriate name given it by one of our prominent writers, a former Toledoan, in an article recently published in the *Pacific Monthly Magazine*. I refer to Mr. Elmer Whyte, formerly of the Toledo *Bee*. I may as well admit in the outset that my own idea of Arizona, at least the southwestern part of it, had always been of an arid, level waste or desert so hot in summer as to make it well nigh impossible for man to exist there; at best he would simply gradually shrivel up and be blown away or die of thirst. Instead, it is a land of sunshine and flowers, birds and fruitage, with many wooded areas, of untold wealth of minerals, of mountains of pineclad grandeur and canyons of eroded and awesome splendor, of water supplies and water power only waiting man's conservation, and of valleys whose silt and glacier-made soil lies hundreds of feet in depth, inviting the most profitable farming and fruit growing for ages to come.

I suppose every one in this intelligent audience of the Toledo Society of Engineers knows the climate in the semi-tropical territory of Arizona. It has its winter or rainy season, with occasional very light frosts during the months of December, January, February and March. Last winter it had a most unusual and almost continuous rainfall in January and February, but from April to November there is practically no rain, except that once in a great while some heavy thunderstorm may break loose in the mountainous country, and the otherwise dry creek beds then carry the water with destructive force.

As before mentioned, there is much rich soil in the level plains and valleys, waiting only for a reasonable regular supply of

moisture to transform these deserts into perpetual gardens. Some valleys particularly are wonderfully fertile. One of these is the Salt River Valley, in the center of which lies Phœnix, the capital of the territory of Arizona. The valley is some 60 miles long and perhaps 25 miles wide, and its inhabitants are convinced that it is the richest garden spot on earth. Irrigation is by no means an experiment in Salt River Valley, for irrigation was attempted and carried on there long ago, as is shown by the remains of canals and ditches leading from the river far out upon the plains, built ages before the white man came. With the advent of the emigrant and white settler, private enterprises of irrigation have been attempted in various localities of the United States, and the Salt River Valley of Arizona has had its water supply company; but it has been the almost universal result of the private irrigation enterprises in the West, from the lack of sufficient capital and the immensity of the undertakings, that failure came to them sooner or later. The works were generally of a temporary nature, fulfilling the promise only so long as average conditions existed. During the time of any unusual drought the water supply failed, and in periods of flood the dam would be washed out and destroyed, followed by financial failure to the water supply company as the usual natural result. Such was the experience of the Salt River Valley Canal and its water preservation and supply enterprises. A brush dam across Salt River some 22 miles above Phœnix, built below the mouth of the Verde River, was taken out by last year's flood, and with it came the failure of the Arizona Water Supply Company. But the passage of the National Irrigation Law, signed by the President June 17, 1902, and the carrying out of its measures brought permanent relief to these people.

The provisions of the Reclamation Law are as follows:

(1) A reclamation fund in the treasury of the United States consisting of the proceeds from the sales of public lands in the sixteen arid and semi-arid states and territories.

(2) A reclamation service in the United States Geological Survey to investigate and report on the irrigation projects for the approval of the Secretary of the Interior, who may authorize the construction and let contracts, providing the money is available in the fund.

(3) The return to the fund of the actual cost of each project by the sale of water rights, payments to be made in a series of instalments running over a period of ten years.

(4) The holding of public lands for actual settlers under the

Homestead Act in small farm units sufficient to support a family, no commutation to be permitted.

(5) The sale of water rights to private land owners, but not for more than 160 acres, making land monopoly impossible and forcing the division of large estates.

(6) The ultimate turning over to the people of the irrigation works, except the reservoirs, to be operated and managed by them under a system of home rule. The actual users of the water in ten years after its completion of the works will have repaid to the government the amount of its loan without interest. The money so returned may again and again be expended for other reclamation works.

So, by the middle of 1905, some $27 000 000 has been derived from the sale of public lands and appropriated for this work, and it is estimated that within the next three years at least $10 000,000 more will be received from the same source, and the object is to spend this money for reclamation where it will do the most good to the greatest number of people. The above amount, increasing every year as you see, will be the working capital for building reclamation works and transforming other deserts into rich farming lands; and we see the importance of it when we remember the enormous extent of the country embraced in the arid regions, — all of two fifths of the United States.

The reclamation work of the Salt River Valley has been one of the first undertakings of the kind under government control since the passage of the act of 1902; and while the great dam has not yet been built, in fact, the building of the dam proper had hardly been commenced during my visit to the site, yet great progress in accessory works has been made. The location of the site is across the river canyon some 75 miles above Phœnix, immediately below the mouth of Tonto Creek, at a point where the river is confined between solid rock walls 500 ft. or more in height above the river bed. Above the dam the valley opens out to some 2 to 5 miles in width between the bluffs, making an excellent natural storage reservoir. The dam as designed has the cross-section of an ordinary masonry gravity dam; that is, its base is wide and its mass great enough to resist overturning from the designed head of 210 ft. of water pressure. However, in general plan the structure is built on a curve of about 400 ft. radius, the skew backs of the arch abutting against the solid walls of the confining cliffs. It will be about 235 ft. long by 160 ft. wide at its lowest foundations, gradually lengthening as

it is built up between its abutments to a total length of 780 ft., and 16 ft. wide at top, with spillways 100 by 20 ft. deep cut out of the solid rock cliffs at each end. The total height of masonry from foundations will be 284 ft. Consider for a moment this great height, comparing it with our Nicholas Building. I learn that that building has a height of 200 ft. from level of sidewalk to roof cornice. This makes this dam some 84 ft., or about seven stories, higher. The estimated amount of masonry in the dam is 300 000 cu. yd. of uncoursed rubble work of sandstone taken from adjoining cliffs, and requiring about 240 000 bbl. of Portland cement in its construction.

The reservoir formed by this great barrier will be one of the largest artificial lakes in the world, 2 to 4 miles wide and some 27 miles long, that is, some 9 miles up Tonto Creek and 18 miles up Salt River. The village of Roosevelt, a thriving town of about 2 000 inhabitants, with electric lights, water works, schoolhouses, stores and churches, is located on a level bench some 30 ft. above water at the confluence of the two rivers, and it will be some 180 ft. to 200 ft. below water after the dam is built and serves its purpose. The capacity of the reservoir will be ten times greater than the Croton Reservoir, and it will contain more water than is stored by the Assouan Dam. It will contain 1 400 000 acre-feet, that is, it would cover that number of acres, or 2 200 sq. miles, one foot deep. The area of the reservoir is 15 000 acres and it drains a basin of 5 756 sq. miles; it is said to contain water enough to supply irrigation for four seasons.

The purpose of the reservoir is primarily to furnish storage to give a needed uniform supply of water during the dry season. A diversion tunnel, 10 by 13 ft., has been built through the bluffs at present low-water level, reaching from above the dam into the river bed below, and after the works are completed the water for irrigation purposes will be diverted through this tunnel and through the present narrow confined river channel for 44 miles and then be diverted through channels to the irrigable lands.

In connection with this dam an 8 by 8 ft. power canal, for most of its length lined with cement, has been built along and through the hills and across some intervening side canyons some 22 miles long, to a point below the dam to furnish the water and head for a power plant to be installed to supply some 5 000 h.p., which power is to be used to lift water for irrigation on mesas or plains on higher levels than the present irrigation canals could supply.

Wagon Road. The question of supplies of material, fuel, tools and machinery, as well as the commissary department for an army of laborers, was an important one to consider, for to reach the site there was but one narrow wagon road with heavy grades over the mountains, and about 40 miles long, to Globe, the nearest town of any importance and the terminus of a local railway branching from the main line of the Southern Pacific Railway, then the only available railroad for transportation. To reach the Sante Fé Railroad, a competing line, a wagon road was constructed 62 miles long to Mesa, 15 miles from Phœnix on Southern Pacific and Sante Fé Railroad, to the cost of which the municipalities of Phœnix, Tempe and Mesa contributed $75 000. The road was constructed by the government engineers and not by contract, and it is one of the most spectacular pieces of engineering in the West. For more than 40 miles it is in the canyon of the Salt River, many miles having been blasted from the precipitous walls. The day laborers were mostly Apache Indians, remnants of Geronimo's band. The road opens up a new region of beautiful and imposing scenery, and when the great dam is completed the Tonto Reservoir and the Roosevelt Dam will surely attract the transcontinental tourist and visitor.

Cement Plant. In the construction of the dam and accessories, some 240 000 bbl. of cement are required. The question of cement was not the least of the problems that had to be taken care of by the engineers. The isolation of the dam site and a tendency on the part of cement manufacturers to place as high a value on their product as they thought it would bear, offered a very serious problem. The first bids on Portland cement were $9 per bbl. delivered at the site, making this item over $2 000 000. Then it was that the geological engineer came into play and showed his usefulness. A reconnaisance of the ground disclosed the fact that a ledge of limestone free from magnesia outcropped just above the dam site, while hills of clay, suitable for cement, were within a short distance of it, only a few hundred feet. Notwithstanding the vigorous protests of cement manufacturers and their offer of cement at about half their former bids, the Secretary of the Interior authorized the building of a cement mill. This mill has been in successful operation for several months and is now turning out about 100 bbl. of first-class Portland cement every day, and will, after complete installing of power plant, make over three times the amount per day, and save in the cost of the dam more than a

million dollars on the price offered by the cement trust. After passing through this small but quite modern cement mill I thought this an excellent opportunity to pick up more knowledge on the subject, and I had at first intended to make this a paper on modern American practice of Portland cement manufacture, but I find that to go into details now would be beyond the limits of this paper, so will simply say that a very fine product of slow-setting cement is being made, excellently fitted for the purposes intended.

I will close by giving the government engineers' estimated cost of the dam and its accessories. I have had access only to the earlier estimate, which gives approximate cost about $2 000 000, but I am told that already nearly $2 000 000 have been spent on the wagon road, cement mill and power canal; its several tunnels and siphons and the dam proper have hardly been begun, so the total cost will reach nearer $4 000 000, the government, I understand, having offered the old Arizona Canal and Water Supply Company for canals, old water rights, etc., about $304 000.

Estimated Cost Salt River Storage Dam at Roosevelt.

Excavations for foundations and river diversion........	$50 000
Cost of cement plant..................................	91 000
260 000 cu. yd. rubble masonry, exclusive power plant and cement, at $3.50..............................	910 000
Power plant, power house and canal, complete..........	188 360
Manufacturing 200 000 bbl. cement at $2.00.............	400 000
Outlet tunnel..	31 450
Gates and machinery....................................	11 600
Outlet towers, shafts and houses.......................	9 000
Viaduct across spillway................................	26 000
Roads and telephones...................................	15 000
Engineering and contingencies..........................	259 860
Damage to private lands................................	42 000
	$2 034 270

Dam 40 ft. higher, with estimated capacity of 1 450 000 acre-feet, would cost approximately $2 700 000.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by February 15, 1907, for publication in a subsequent number of the Journal.]

OBITUARY.

Albert Henry Zeller.

MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

ALBERT HENRY ZELLER was born in St. Louis, January 20, 1867. He was the second son of William Zeller and Christine Haarstick-Zeller. His death occurred in St. Louis on the second day of November, 1906, at the age of thirty-nine years, after an illness of several months. He is survived by his mother, two brothers, William F. and Eugene C. Zeller, and one sister, Mrs. F. W. Frerichs of St. Louis.

When young Zeller was three years old his parents took him to Germany for a year, returning to this country in 1871. At this early age he developed a love for music and was allowed to begin his studies on the violin. In later years, without permitting his love for music to encroach upon the time due his chosen profession, that of civil engineer, he devoted many of his leisure hours to the violin, to his own enjoyment and that of a few chosen friends. Zeller received his early education at the St. Louis public schools, attending the Peabody School at St. Louis from 1873 until 1878, when he was sent to a French school at Lausanne, Switzerland. He remained at Lausanne two years, taking a regular course, but devoting considerable time to the study of the French language, in which he became very proficient. In 1880 he returned to St. Louis and attended Smith Academy and later Washington University, graduating from the former in 1883 and from the latter, with the degree of Bachelor of Engineering, in 1887. He was particularly fond of mathematics and was ever ready to apply mathematical solutions to problems coming under his notice.

Zeller's first employment after graduation was as draftsman and assistant engineer, St. Louis, Iron Mountain & Southern Railway, at St. Louis until April, 1889. From April, 1889, until May, 1891, with the exception of a period from May to December, 1890, during which time he traveled in Europe, he was engaged as assistant engineer with the St. Louis Merchants Bridge Terminal Railway, St. Louis, Mr. Robert Moore, Chief Engineer. From May, 1891, to November, 1892, he was employed in the designing department of the Edge Moor Bridge Works, Wilmington, Del. From February to May, 1893, he was principal as-

sistant engineer, St. Louis Terminal Railway Association, in charge of erection of train shed at the new Union Station. In May, 1893, he was appointed engineer assistant to the president of the Board of Public Improvements at St. Louis, a position which he filled for four years with much credit to himself and much profit to the city of St. Louis. Robert McMath, who was president of the Board of Public Improvements at the time, states, writing of Zeller: "He declined reappointment for another term, intending to go to Europe for a long stay. I was sorry to lose him, for he was worthy of confidence, and our relations were wholly pleasant to both, as also with all who came in contact with him." Resigning from the service of the city in 1897, he went abroad for two years, and returning, opened an office at St. Louis for the general practice of his profession, at which work he was engaged at the time of his death. For some years past, however, he had devoted much of his time to managing the estate of his family and, though he kept abreast of the time in his profession and was well posted on the engineering problems of the day, he did not engage in extensive practice.

His services in behalf of the Engineers' Club of St. Louis were marked by the same painstaking care and thoroughness of detail which he applied to every problem intrusted to him. He was naturally of a modest and retiring disposition, never inclined to push himself to the front, but his ability and trustworthiness were recognized by the Engineers' Club in frequent appointments for committee work. When the Club moved to its present quarters a few years ago, Zeller was appointed on the committee on quarters. His work as a member of the committee was untiring and to him, more than any one else, the Club is indebted for the pleasant arrangement of the quarters which we now enjoy.

Zeller had traveled much, having visited Europe no less than five times. He was a man of broad mind and sound judgment, and without guile or deceit. To know him was to admire him. Justice and truth and gentleness were embodied in his every act and thought. His friends thought of him as one on whom they could depend for assistance in every good cause, and, if need be, for such sacrifices as friendship calls for. In his untimely death the engineering profession has lost a member whose life can ill be spared. The community in which he lived, the associates who enjoyed his friendship, will remember him and continue to feel the influence of his thought and his life, and he will not have lived in vain.

It seems but proper to add the following testimonial by Mr. William Chauvenet:

"How pleasant it is, after all, to speak of one whose memory must ever be a sweet one and whose life as we recall it will ever help to make us better men. It was his gentleness in all his relationships, and his justice in all dealings with men, that most impressed me. He was strong to see the right and fitting thing to be done in any emergency, and his clear vision was ever helpful to his friends. His command of himself in all positions, and the absence of any tinge of severity in the exhibition of such command, was one of his most noted characteristics. Ever considerate of others, he nevertheless made you feel that he was somehow under obligations to the one he was helping, and this mark of the true gentleman was one of his charms as a companion and as a friend. Of his own fortunes, whether good or bad, he never spoke, while his ever active interest in the good fortunes of others, and his sure sympathy in times of loss, made him one whom we naturally sought out whenever the clouds hung low. Assuming nothing, yet was his judgment sound, and in all his relationships with men, and especially with his comrades, nothing could disturb his sweetness. I know I am naming the characteristics of a rare man and one more associated with the old school than with our aggressive and unconventional times, yet such was my friend and dear companion. He is to me alive and often present in our midst, because his qualities partook of those things which do not die but live on, safe within the hearts of those who had learned to love him while here."

EDWARD FLAD.
R. H. FERNALD.
W. G. BRENNEKE.

Freeman Clarke Coffin.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

FREEMAN CLARKE COFFIN was born in Boston on September 14, 1856, the son of Alonzo King and Mary E. Coffin. He received his early training at the public schools of Patten, Me., to which place his family moved two years after his birth. At the age of fourteen years, when the support of the family fell upon him, he became a clerk in a country store. A year or two later he began the manufacture of furniture in a small way, and in

the course of the next ten years bought an old planing mill and water privilege in Patten, and built up the largest furniture manufacturing establishment in the community.

Feeling that this business did not offer him a satisfactory outlook, he returned to Boston at the age of twenty-six, and became a pattern maker at the works of the Coffin Valve Company, then operated by his uncle, Mr. Z. E. Coffin. There he remained two years, until 1884, when he entered the employ of Mr. M. M. Tidd, of Boston, as one of his engineering assistants. Mr. Tidd was at that time one of the best known hydraulic engineers in New England, devoting himself largely to water-works construction. For ten years Mr. Coffin remained with Mr. Tidd, during the latter eight of which he was Mr. Tidd's principal assistant. This was, perhaps, the formative period in Mr. Coffin's career, for he was intensely interested in his new employment and spent all his leisure hours in making good the lack of early technical training and in perfecting himself for the broader field which he was to enter upon leaving Mr. Tidd's office.

On January 1, 1894, he opened his own office in Boston, and, in 1905, took into partnership his principal assistant, Mr. Lewis D. Thorpe.

During the last twelve years of his life Mr. Coffin designed and supervised the construction of many water and sewerage works, and reported upon many engineering projects, the most important of which were the water works at Cambridge, Haverhill, Ipswich, Merrimac, Walpole, Mass.; Bar Harbor, and Seal Harbor, Me.; Walpole, N. H., and Windsor and Proctor, Vt., and the sewerage works at Charlottetown, P. E. I.; Marion, Mass.; Proctor, Vt.; Chatham, N. B., and Truro, N. S.

As an expert in water-works valuation and water power cases, Mr. Coffin's opinion was often sought. He acted as arbitrator in the valuation case at Bartlett, N. H., and as referee in the water power case at Hinsdale, N. H. He gave testimony in the Spot Pond, Haverhill, West Springfield and Athol cases in Mass.; at Newmarket and North Conway, N. H.; at Gardiner, Waterville and Brunswick, Me.; and at Ithaca, N. Y. He also made report and valuation upon the works at Baton Rouge, La.; Barre, Vt.; Claremont, N. H.; Swampscott, Revere and Amesbury, Mass., in all of which cases, excepting Baton Rouge, his report formed the basis of settlement with the water companies located at those places, without appeal to the courts. He testified in suits for the diversion of water at Attleboro,

Taunton and Waltham, Mass.; Woonsocket, R. I.; Wolfboro, N. H., and at Bar Harbor, Me.

Mr. Coffin was a member of the American Society of Civil Engineers, the Boston Society of Civil Engineers, the New England Water Works Association and the Canadian Society of Civil Engineers. The formation of the Sanitary Section of the Boston Society of Civil Engineers was due to his inspiration, as was in no small degree its success.

In spite of the demands of his professional practice he found time to take a hearty and active interest in the work of these societies, as is shown by the admirable technical papers and discussions presented by him before them. He contributed valuable discussions to papers upon the "Financial Management of Water Works," and "The Valuation of Water Works," published in the *Transactions of the American Society of Civil Engineers*, and presented a paper upon the former subject before the New England Water Works Association. He also contributed important papers before the latter association upon "Standpipes and Their Design," "Friction in Several Pumping Mains," "Corrosion of Pipes," "Application of Gas, Gasoline and Oil Engines to Pumping Machinery," "Covered Reservoirs and Their Design," and others of lesser importance. His paper upon "A Few Notes on Cast Iron Pipe," was the forerunner of the general discussion in engineering societies upon standard specifications for cast-iron water pipe, and led to his appointment as chairman of the committee of the New England Water Works Association, which drafted the "Standard Specifications for Cast-Iron Pipe and Special Castings," now coming into general use. He had also served for several years in the same society as chairman of a special committee upon "Meter Rates." In 1897 Mr. Coffin published his handbook of "Graphical Solution of Hydraulic Problems," which has won very favorable comment, and passed through two editions.

Mr. Coffin took an active interest in public questions of the day, and frequently took part in discussions at the Twentieth Century Club, of which he was a member.

At the time of his death Mr. Coffin was a vice-president of the Boston Society of Civil Engineers, chairman of its Sanitary Section, and had been nominated for vice-president of the New England Water Works Association.

He died at his home in West Medford on November 11, 1906, and is survived by his widow and four sons.

Without early technical training, and though he took up

engineering work late in life he attained in a comparatively short professional career to the foremost rank of the civil engineers of New England. Mr. Coffin was a fine example, not only of the self-made but of the well-made man. He was simple in his tastes and daily life and a firm believer in the gospel of work, broad in his point of view, and courageous but courteous in action. Honest, fair-minded and generous, he won for himself the respect of all and the admiration and affection of the younger men in the profession, in whom he always took a warm and friendly interest. In his death the profession has suffered the loss of a strong and independent thinker, the community of an upright and public-spirited man.

LEONARD METCALF,
WILLIAM S. JOHNSON,
Committee.

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Association
OF
Engineering Societies.

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PROCEEDINGS.

Montana Society of Engineers.

Butte, Mont., May 12, 1906.—The regular meeting of the Montana Society of Engineers was held at the Society Room, 225 North Main Street, Saturday evening, May 12, 1906, President Dunshee presiding. Quorum present. The minutes of the previous meeting were read and approved.

The Secretary reported the death of Thomas T. Baker, a valued member of the Society, and Messrs. Barker, Hobart and McArthur were appointed a Committee on Resolutions. The Committee on Furniture reported as having completed its labors, and, the result being examined and approved, the committee was discharged.

The Secretary was instructed to have last year's periodicals bound and properly classified in the new bookcases.

Adjourned.

Clinton H. Moore, *Secretary.*

Association of Engineering Societies.

Vol. XXXVII. SEPTEMBER, 1906. No. 3.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 16, 1906. — The 617th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, May 16, 1906, President Layman presiding. Thirty-three members and eleven guests were present.

The minutes of the 616th meeting were read and approved.

Applications for membership in the Club from Fred Blattner Adam and Alfred E. Lindau were presented.

Mr. Robert Loathan Lund and Mr. F. R. Mott were elected to membership in the Club.

Mr. W. H. Bryan, who had recently returned from San Francisco, spoke of the great need of technical books, etc., for the use of the engineers' club of that section. It was moved by Mr. Fish that the sum of $100 be presented to the Technical Club of the Pacific Coast to be used at its discretion; and that a committee of two be appointed to select such duplicate copies of books in the library of the Engineers' Club as may be of use to the engineers of San Francisco and to forward the same to the Technical Club of the Pacific Coast. Seconded by Mr. Moreno. Motion carried. The President appointed Mr. W. H. Bryan and the Secretary as the committee.

The Secretary read a letter from the Board of Water Supply of the city of New York relating to examinations for assistant engineers, topographical draftsmen and rodmen.

The Librarian reported that the books had been entirely rearranged in the Library and explained the present system.

The Secretary reported that the Annual Bulletin was being prepared and would be published as speedily as possible.

The paper of the evening upon "Recent Developments in Electric Railroading," by Prof. A. S. Langsdorf, presented a review of the most important developments in heavy electric railroading in the United States and abroad, with explanations of the types of power, distribution and rolling-stock equipment and their characteristics. The descriptions were illustrated by lantern slides. The discussion was participated in by Messrs. Colby, Beebe, Moreno, Layman, Tropp and McMath.

The Secretary announced that Mr. Bryan had consented to present a paper on the engineering features of the San Francisco earthquake at the next meeting of the Club.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, June 6, 1906. — The 618th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, June 6, 1906. In the absence of President Layman, Vice-President Fish presided. Thirty-one members and three visitors were present.

The minutes of the 617th meeting were read and approved. The minutes of the 408th meeting of the Executive Committee were read.

Applications for membership from F. B. Adam and A. E. Lindau, as approved by the Executive Committee, were presented for election. These applications were referred back to the Executive Committee with instructions to the committee to designate the class of membership to which each applicant was proposed.

The Committee on Extension of Membership presented a report of progress.

Mr. W. H. Bryan then gave an informal talk on "The Engineering Features of the San Francisco Earthquake." Considerable interest was taken in the discussion, which was participated in by Messrs. Holman, Hanna, Murphy, Fish, Van Ornum, McCulloch, Greensfelder, Henby, Ockerson and Bryan.

Mr. Fish reminded the Entertainment Committee that it was the duty of the committee to arrange for numerous trips during the summer recess.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, September 19, 1906. — The 619th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, September 19, 1906. President Layman presided. There were present thirty-nine members and seventeen visitors.

The minutes of the 618th meeting were read and approved. The minutes of the 410th meeting of the Executive Committee were read.

The applications of Alfred E. Lindau for active, and of Fred Blattner Adam for associate membership were voted upon and the applicants declared unanimously elected. The application of John I. Boggs was read and referred to the Executive Committee.

The paper of the evening on the "Reconstruction of the Olive Street Railway Tracks" was presented by Richard McCulloch. A very interesting account was given of the methods pursued in track relaying on the most important thoroughfare of St. Louis, — Olive Street. The paper was illustrated by slides, clearly showing the equipment specially designed for expeditious work in blasting out with dynamite the old cable slot, which lay for years imbedded in solid concrete; and the concrete mixer adapted for effective mixing and discharging of concrete beneath and between the ties, forming a solid roadbed four miles in length. Some important figures in the cost of construction were given, which will form a valuable record for future reference. The discussion was

participated in by Col. John I. Boggs, of Milwaukee; Capt. Robt. McCulloch, Messrs. Moore, Flad, Pfeiffer and Russell. Colonel Boggs compared the advantages of the T-rail, used almost exclusively in Milwaukee for street railway work, with that of the grooved Trilby rail required by St. Louis ordinances. From experience Colonel Boggs stated that the life of the T-rail outlasts that of the Trilby rail more than twice. The T-rail also permitted of rapid-transit conditions in connection with suburban and interurban traffic, which the Trilby rail did not. Mr. Boggs made a strong plea for more intelligent city legislation in this respect.

On motion duly carried the meeting adjourned.

F. E. BAUSCH, *Secretary pro tem.*

ST. LOUIS, OCTOBER 3, 1906. — The 620th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, October 3, 1906. President Layman presided. Twenty-four members and nine visitors were present.

The minutes of the 619th meeting were read and approved.

The application of Edwin Dwight Smith was read and referred to the Executive Committee. Mr. John I. Boggs, of Little Rock, Ark., was elected to non-resident membership.

The Secretary read a letter from Colonel Ockerson, stating that he had presented to the Club a copy of "Report of the Board of Consulting Engineers for the Panama Canal," together with maps and diagrams. A vote of thanks was extended to Colonel Ockerson for the donation.

A letter was read from Mr. Otto von Geldern, Secretary of the Technical Society of the Pacific Coast, expressing the appreciation of the Society for the donation of books by the Engineers' Club of St. Louis.

The Secretary read letters calling for men to fill various engineering positions.

The attention of the Club was called to the medal and diploma presented to the Club by the Louisiana Purchase Exposition.

The paper of the evening, entitled, "Present Tendencies of Power Plant Design," was presented by Mr. E. R. Fish. The paper was profusely illustrated by lantern slides and showed the development of steam power plants; electric power with belt transmission; electric power, direct connected; water power; steam turbines; gas producer and gas engine installations, and the transitions from one type of power generation and distribution to another.

After discussion of the paper by Messrs. Lichter, Bryan, Fernald, Layman and Fish, the meeting adjourned.

R. H. FERNALD, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., OCTOBER 11, 1906. — A special meeting of the Civil Engineers' Society of St. Paul was held at 2 P.M. Present twelve members, President Claussen in the chair.

The Secretary stated the purpose of the meeting and Mr. Rundlett presented a resolution which was adopted by a rising vote.

Resolved, That the Civil Engineers' Society of St. Paul endorse the following memorial:

We meet to-day in special session to honor the memory of Mr. C. A .Winslow, whose sudden death has afflicted this Society with the loss of a faithful officer, has deprived the department in which he has served for the past nineteen years of an efficient and conscientious worker and has bereaved his friends and associates of a man held in affection and the highest esteem.

We extend to his wife and family our sincere sympathy.

On motion of Mr. Starkey, Mr. G. Z. Heuston was unanimously elected as librarian in the place of Mr. Winslow, deceased.

The election of Mr. A. R. Starkey as representative on the Board of Managers of the Association of Engineering Societies in place of Mr. Powell, resigned, was ratified.

The following applicants were elected to membership: Mr. Garrett O. House, Mr. R. A. Tanner, Mr. John S. Potter.

A vote of thanks was accorded Mr. Geo. L. Wilson and the management of the Twin City Rapid Transit Company for courtesies extended to members of the society on September 15.

C. L. Annan, *Secretary.*

Montana Society of Engineers.

Butte, Mont., October 13, 1906. — The regular meeting of the Montana Society of Engineers was held at the society room, 225 North Main Street, Saturday evening, October 13, 1906, with a good attendance of members and President Dunshee presiding. The minutes of the last meeting were approved as read. Applications for membership from George A. Griggs and Sedman W. Wynne were read, and after approval the Secretary was instructed to circulate the necessary ballots.

The Resolutions Committee on the death of Thomas T. Baker were granted further time to prepare their report. The resignation of John T. Morrow was read and accepted.

The President announced the following Committee on Nomination of Officers for the coming year: Messrs. Charles W. Goodale, Eugene Carroll and George E. Moulthrop.

The Secretary announced the death of Charles W. Leimer, also of George H. Robinson, and the chair named the following committees on resolutions: In case of Mr. Leimer, Messrs. Robert K. Humphrey, Charles W. Goodale and Clinton H. Moore; in case of Mr. Robinson, Frank L. Sizer, William F. Word and Albert S. Hovey.

Adjournment followed.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, October 5, 1906.— Regular meeting held in the Mechanics' Institute Library hall, and called to order at 8.30 p.m.

A quorum was present.

The Secretary read the following report:

To the Members of the Society, — The Secretary took it upon himself to call this, the first regular meeting of the Technical Society, since the catastrophe occurred on April 18, 1906.

The great fire destroyed every possession of the Society, books, records, accounts, copies of the Constitution and all the unbound publications of its transactions, accumulated since 1884. The library had been turned over to the Mechanics' Institute when the Society entered into an arrangement with it to confer upon our members the privileges of the Institute. The Mechanics' Library building, 31 Post Street, was destroyed and all the books with it. The Secretary's office in the Academy of Sciences Building was burned on the morning of the catastrophe, and with this destruction the Technical Society lost all its possessions. The money accounts were in the hands of the Treasurer. These were saved and the cash in bank will be accounted for properly by the Treasurer's report which he will hand you in due time.

Immediately after the fire, the Secretary opened an office in the residence of the Treasurer, Mr. E. T. Schild, 1908 Broadway, San Francisco, who kindly placed at the disposal of the Society his front parlor, where a number of meetings were held in April and in May, and where the business of the Society was transacted for three months. These meetings were attended by technical men irrespective of society affiliation, and their discussions centered upon methods of construction in rehabilitation of buildings.

For the benefit of our refugees, an address book was started, and many engineers registered so that they could be referred to when wanted.

Through the kind offices of several eastern societies and engineers (notably the American Society of Civil Engineers and Mr. John C. Trautwine, Jr., of Philadelphia), stationery, books, drawing instruments and office supplies were sent to the Secretary, an invoice of which is hereunto attached. These were disposed of by him at his temporary office, 1908 Broadway, San Francisco, after the great fire.

A meeting was held by a committee, of which Mr. Edwin Duryea, Jr., was chairman, and which consisted of the following members of the American Society of Civil Engineers and of the Technical Society of the Pacific Coast: Messrs. W. J. Cuthbertson, W. R. Eckart, William Ham Hall, Marsden Manson, R. W. Myers, Franklin Riffle, Luther Wagoner and Otto von Geldern.

Mr. Von Geldern explained in detail the condition of the Society the donations received, and presented invoices and correspondences, all of which were read and laid before the committee for its action.

The committee thereupon discussed the best means of disposing of the supplies with a disposition to carry out the spirit of the gift.

Mr. Eckart offered a resolution that the Secretary of the Technical Society put advertisements in three of the daily newspapers of San Francisco every alternate day for six days, *i.e.*, three individual insertions, these to announce to engineers and technical men that supplies are on store at the temporary office; that they will be distributed by the Secretary to those in need of them; and that any engineer, draftsman, surveyor or technical man may call for assistance, irrespective of membership in any of the local or national societies; those in need to address the Secretary and enclose a list of the articles required by them at the present time; the Secretary to be instructed to file these wants in the order of their receipt, and to supply those who call for them, until the supplies are exhausted. Discriminating against no one, the instructions authorize the Secretary to furnish those first who call first, serving the articles as long as they will last.

This resolution was seconded by Mr. Wagoner and carried unanimously by the committee members present.

The Secretary was instructed to defray all expenses out of the fund donated by eastern friends, the various donations to be placed in the hands of the Treasurer, who is to render an account of the disposition of the money.

It was also ordered that the Secretary inform the chairman of the committee, Mr. Duryea, who was absent, of the transactions of the meeting and to request him to announce to the local members of the

American Society of Civil Engineers and before the Municipal Advisory Committee of Forty, that these supplies were on hand and that they would be distributed as set forth in Mr. W. R. Eckart's resolution.

With this official authority behind him, the Secretary inserted notices in the daily newspapers as follows:

To Engineers and Technical Men: Through engineering societies of the East, a lot of engineering office supplies, consisting of scales, triangles, field and pocket books, instruments, paper, etc., have been sent to the Secretary of the Technical Society for gratuitous distribution to those who have been burned out. Application may be made by any engineer, draftsman, or architect by addressing OTTO VON GELDERN, 1908 Broadway, San Francisco.

EDWIN DURYEA, JR., *Chairman of Committee.*

For a period of about one month there were daily calls for supplies by a great many representatives of the technical professions who had lost all their tools, and who, willing to work, were not able to obtain them elsewhere, even if they had had the money to pay for them.

It necessitated considerable patient work, which was done cheerfully by members of the Secretary's family and particularly by the wife of the Technical Society's Treasurer, Mrs. E. T. Schild, and Edward von Geldern, who kept a faithful record of every article that was disposed of in this way.

The supplies most in demand were drawing instruments, scales, pencils, triangles, T-squares, straight-edges, engineering pocketbooks, field books, tape-lines, inks and colors.

Papers, tracing cloth and blue-print paper were not required to such an extent, because these articles were usually furnished by the firms who employed the men, and had been obtained from the larger coast cities like Los Angeles, Portland and Seattle.

There is no doubt that a great deal of good was accomplished by this emergency help. It is true that we could not furnish every caller and every technical man with what he wanted, but we did all we could do, and distributed everything to the best of our ability and with ordinary discretion, making the supplies last as long as we could.

Here follows a list of donations as they were received from day to day at the Secretary's office:

DONATIONS

MRS. E. E. HOLMAN, 1020 Chestnut Street, Philadelphia:
- Office tools and drawing instruments, scales, etc.

W. G. KIRCHOFFER, Consulting Engineer, Vroman Building, Madison, Wis.:
- Office instruments.

GEORGE F. SCHILD, Naval Architect, Vallejo, Cal.:
- Office instruments, scales, maps, etc.

ARTHUR E. NORTON, Division of Engineering, Harvard University, Cambridge, Mass.:
- 1 package of triangular scales.
- 25 40° triangles.
- 25 60° triangles.

E. L. CORTHELL, Consulting Engineer, New York:
- 12 compasses, 12 ruling pens, *from Theo. Alteneder & Son, Philadelphia.*
- 1 gr. 2H "Koh-I-Noor" pencils, *from L. & C. Hardmuth, New York.*
- 2 Vega's logarithms, *from Lemcke & Buechner, New York.*
- 2 Lufkin tapes, 100 ft., *from Patterson Brothers, New York.*
- 12 Carnegie pocketbooks, *from United States Steel Products Export Company, New York.*
- 6 Smoley's tables, *from Engineering News Publishing Company, New York.*

12 wooden triangles, 30°–60°,	24 point protectors,	*from E. G. Soltman, New York.*
12 wooden triangles, 45°,	24 ink erasers,	
300 Record thumb tacks,	24 pencil erasers,	
1 gr. No. 312 pens,	12 4-ft. folding rules,	
1 gr. No. 170 pens,	4 blue pencils,	
24 penholders,	3 red chalks,	

Through JOHN C. TRAUTWINE, Jr., and by the courtesy of WILLIAMS, BROWN & EARLE, Philadelphia:

- 2 sets drawing instruments.
- 44 triangles, of different sizes, wood and celluloid.
- 9 curves of different sizes.
- 1 doz. pencils.
- 4 Sexton's omnimeters (cardboard).
- 1 Cox computer (paper).
- 73 flat scales, 12-in. long, wood.
- 4 flat scales, 18 in. and 24 in. long.
- 19 triangular scales, 12 in. long.
- 1 extension foot-rule, 4 ft.
- 68 small off-set scales, 1 in. to 6 in. long.
- 4 wooden protractor scales.
- 27 small triangular off-set scales.
- 13 ruling pens.
- 6 6-in. dividers.
- 6 steppers.
- 4 bow-pens.
- 1 set compass, with pencil and pen.
- 1 T-square.
- 4 doz. pen points, assorted.
- 1 small protractor.
- 1 package tables (circles, etc.).

K. J. C. ZINK, Assistant to Chief Engineer, Grand Trunk Pacific Railway, Montreal, Quebec:

- 15 bottles drawing ink.
- 1 case pencils.
- 11 large pieces soft rubber.
- 12 point protectors.
- 2 doz. drawing pencils.
- Assorted ink erasers.
- 1 doz. blue pencils.
- 1 doz. yellow pencils.
- 4 boxes talcum.
- 2 boxes writing pens.
- 1 bottle paste.
- 1 bottle white ink.
- 6 ruling pens.
- 1 scale.
- 2 crayons.
- 1 curve.
- 8 triangles.
- 12 brushes.
- 5 penholders.
- 4 T-squares.

AMERICAN SOCIETY OF CIVIL ENGINEERS, New York:

- 25 sets instruments.
- 25 triangular scales.
- 25 small brass protractors.
- 18 straight edges, 36 in.
- 5 straight edges, 30 in.
- 2 straight edges, 42 in.
- 25 triangles, 60°–30°.
- 25 triangles, 45°.
- 2 Stadia slide rules.
- 24 tape lines.
- 24 field books.
- 24 level books.
- 6 rolls Imperial tracing cloth.
- 3 rolls, 100 yd. each, detail paper.
- 2 rolls profile paper.
- 2 rolls cross-section paper.
- 6 rolls economy paper
- 20 rolls blue-print paper.
- 6 bottles Columbia ink.
- 10 boxes tacks.
- 6 boxes assorted water colors.
- 12 doz. Paragon pencils, 6H.
- 12 doz. Paragon pencils, 2H.
- 12 doz. rubbers.
- 6 gross pens.
- 2 doz. plumb bobs.
- 1 doz. red pencils.
- 1 doz. blue pencils.
- 12 cross-section books.

Mr. GEORGE C. POWER sent a transit, to be loaned to any engineer in immediate need.

Mr. H. S. CROWE, of the Modesto Irrigation District, expressing sympathy, offered a blue-print of plans of the district.

Mr. ERNEST MCCULLOUGH, Chicago, sent a number of small instruments and office tools.

A number of smaller donations were sent, all of them acknowledged with the appreciation of the Technical Society, and distributed with the rest.

One hundred and ten technical men were aided by these donations; their names were taken down and the articles given them placed against them.

At the present date there are left over and undistributed the following articles, which the Technical Society may now dispose of as may be deemed best:

STOCK ON HAND:

- 5 sets of drawing instruments.
- 1½ doz. field books.
- 3 omnimeters.
- 1 steel tape.
- 4 metallic tapes.
- 17 plumb bobs.
- 20 doz. pencils.
- 2 boxes of rubbers.
- 1 roll profile paper.
- 3 rolls sketching paper.
- 3 rolls tracing cloth.
- 18 rolls blue-print paper.
- 3 Trautwine's "Pocketbooks."
- 1 table of logarithms.

The following books were donated. The pocketbooks were given

away, and a few of the others sold to those who could afford to pay for them.

THOS. A. EDISON:
1 doz. Trautwine "Pocketbooks."

J. T. FANNING:
"Water Supply Engineering."

CHAS. J. CHURCHILL:
Shunk's "Pocketbook."

JOHN C. TRAUTWINE, Jr.:
16 "Pocketbooks" (Trautwine of all kinds and editions).

SANFORD E. THOMPSON:
"Concrete, Plain and Reinforced."

HORACE ANDREWS:
One case, containing fourteen engineering books on different subjects.

THE ASSOCIATION OF ENGINEERING SOCIETIES, Mr. Fred. Brooks, Secretary, Boston:
One set copies of the JOURNAL from the beginning, with the exception of certain numbers which the Association does not possess.

ENGINEERING SOCIETY OF WESTERN PENNSYLVANIA, F. V. McMullin, Secretary:
"Proceedings" of the Society, excepting Volumes ii, iii, iv and vii; and a tin box filled with draftsmen's articles and small books.

ENGINEERS' CLUB OF ST. LOUIS, R. H. Fernald, Secretary:
Transactions of the American Society of Mining Engineers, Volumes ii, v, vi, xiv to xxvi inclusive.
Journal of the Association of Engineering Societies, Volumes i to xiv inclusive (1881–1895), xvi, xvii, xix, xx–xxv, xxx, xxxiii.
Report of the Mississippi River Commission, 1883.
"Tests of Metals," 1881, 1884.

O. CHANUTE, Consulting Engineer, Chicago, Ill.:
Seven boxes of JOURNALS, with a check for $75.
Railroad Gazette and other engineering papers.

H. G. RICHEY, Wheeling, W. Va.:
Handbook.

WESTERN SOCIETY OF ENGINEERS, J. Warder, Secretary:
Offered copies of "Proceedings" and whatever may be of use in the way of literature whenever the Society would be ready to receive it.

A. M. STEGER, Civil Engineer, Pueblo, Mexico:
Eight books on different technical subjects.

THE U. S. GEOLOGICAL SURVEY, Washington, D. C., Mr. E. M. Douglas, Geographer:
Announced under date of June 23, 1906, the shipment of one box containing books, and of a second box containing 32 steel tapes and 2 sets of drawing instruments. Mr. Douglas wrote that the steel tapes were contributed by the Lufkin Rule Company, of Saginaw, Mich.; the drawing instruments were sent by E. C. Held, of the Treasury Department; the books were contributed by various people. Messrs Bausch, Lomb, Saegmuller Company, of Rochester, N. Y., have promised to send a transit and level.

The above boxes or articles as enumerated in the letter from Mr. Douglas have not been received to date, although diligent inquiry has been made from time to time at the railway offices.

JOHN C. TRAUTWINE, Jr.:
Eleven books on different electrical subjects.

With great courtesy several publishing companies of the East offered liberal inducements in the sale of technical books to our engineers. Among these may be mentioned the Engineering News Publishing Company of New York, who offered a reduction of one third on any technical book in its catalogue.

The *Engineering Record* offered similar advantages, and stood ready, for a long time, to publish any article for the Society to aid it in its work.

The Van Nostrand Company offered a donation of books from its catalogue to the value of $250, not strictly confining itself to engineering literature. Upon the receipt of a list a shipment will be made whenever this may be expedient.

Mr. Chas. Warren Hunt, secretary of the American Society, wrote as follows:

"I am authorized to send you, for your Society, as complete a set

of our transactions as we have, as soon as you indicate that you have a place where it may be of use to engineers. I will, therefore, have a set made up ready for shipment, and as soon as I hear from you, will send them.

"At the same meeting I suggested that a number of our members in San Francisco might have lost their libraries through fire, and would probably be glad to replace at least some of the publications of this Society, and in order to make it easy for them to do so I am authorized to replace any of our publications so lost to our members, giving them a discount of 75 per cent., which will make such publications very cheap, probably somewhat less than their actual cost."

In the same manner encouraging offers were made to us that still hold good and that may be taken advantage of at any time. Similar offers were made to Mr. Teggart, librarian of the Mechanics' Institute, and he, with commendable zeal, has made many purchases since the fire for the Institute, with the main object in view of rehabilitating a technical library as soon as possible in San Francisco.

In the present library building, the first to be built on the ruins, you will find all the recent technical books that the profession is in search of usually, and I recommend that the JOURNALS, etc., now in store at my residence be turned over to the Mechanics' Institute Library for shelving.

OTHER DONATIONS.

Immediately after the catastrophe, donations were made to the Society in money, until the Secretary informed the kind donors that there was no longer any need for monetary assistance, but that the loss felt most by our engineers was the destruction of almost every technical book and journal in the town.

Of money received and expended the following statement is made:

RECEIPTS.

May 10	Collected at the meeting of the Engineers' Club, Philadelphia, May 5,	$25.00
,, 10	John H. Converse, Baldwin Locomotive Works	5.00
,, 12	Wm. L. Austin, Baldwin Locomotive Works	25.00
,, 12	Wilfred Lewis, member Engineers' Club, Philadelphia	10.00
,, 12	G. H. Herold, Division Engineer, Great Western Railway, Redwing	5.00
,, 14	Sale of a pocketbook	2.50
,, 16	Donation from the Link Belt Engineering Draftsmen, through Mr. Luders	45.00
June 1	Through Mr. W. H. Bryan, who, after having pleaded for the engineers before the Engineers' Club of St. Louis, caused the club to offer a donation of	100.00
June 2	Engineers' Club, Philadelphia	3.00
June 4	O. Chanute, donation	75.00
July 18	E. M. Douglas	.75
,, 18	Sale of a scale	2.50
,, 18	Sale of a tape and books	15.00
	Total	$313.75

EXPENDITURES.

May 10	Insertion in newspapers for meetings and notifications	$12.80
to	Postage	5.00
Sept. 1,	Stationery	4.50
1906.	Expenses to obtain freight from Oakland	2.00
	Expressage on boxes	18.15
	Telegrams	11.95
	Advertisement to call for articles to be distributed	18.30
	Labor in handling boxes and office assistance	19.40
	Stenographer and typewriter	5.00
		$97.10
	Balance turned over to the Treasurer	216.65
	Total	$313.75

Donation of Clothing.

Very soon after the fire, letters were received from Mrs. Trautwine, of Philadelphia, offering her kind offices in procuring clothing to be distributed among those in need.

Mr. George W. Dickie, the President of the Technical Society, who was in Philadelphia during the catastrophe, and who is there still, attended meetings of the Engineers' Club of Philadelphia, and on May 26 addressed the club regarding the earthquake at San Francisco and the probable destitution of the engineers of our city.

Mrs. Trautwine's communications containing her offer to send clothing to us were submitted to Mrs. Schild and to Mrs. Von Geldern, who were willing to take it upon themselves to see that donations of this character were placed where they would do most good. Mrs. Von Geldern communicated directly with Mrs. Trautwine, accepting her kind offer, and this lady thereupon entered into the spirit of trying to help others with all the enthusiasm of her generous nature, interesting all her friends in Philadelphia to lend assistance.

Although this clothing was shipped soon after the fire, it did not reach San Francisco for several months,— this is more particularly the case with a shipment from Rochester,— which caused the unfortunate condition of not being able to render aid when it would have been most appreciated, that is, at an early day after the calamity. However, when three cases arrived from Philadelphia, the ladies did everything in their power to transfer these contributions to those who were needy. Not necessarily was this restricted to any particular calling or class of people, but where it was definitely known that clothing was wanted for men, for women and particularly for children, it was given with readiness and with the idea of acting in the spirit in which the donations were made.

We have received in all five cases, containing male and female clothing, shoes, handkerchiefs, overcoats, shirts, collars and similar wear in great variety, collected from those who were willing to part with some of their apparel. It came from the families of engineers mostly. Three cases were sent by Mrs. J. C. Trautwine, Jr., of Philadelphia, and two cases by John F. Skinner, secretary of the Rochester Engineering Society; the latter were nearly two months on the way in freight transit.

Another box, promised at the time by Mr. George A. Ricker, acting chief engineer of the Pittsburg, Binghamton & Eastern Railroad Company, has not yet been received. It will be turned over to the Society as soon as it does arrive.

From the contents of this report it may be seen that the Technical Society of the Pacific Coast has not been idle.

Its members were scattered in all directions after the catastrophe, and their addresses were unknown. It was difficult to get them together; repeated calls for meetings advertised in the papers, — costly in themselves, — never accomplished more than the gathering of a few.

The interest in structural work caused the organization of a Society of Structural Engineers, for which there was an immediate field. The Technical Society might have undertaken this work, but in the earlier excitement of military rule and the loss of so much, every one had to think of something usually so near home that the thoughts for the Society's future were not uppermost. It had lost everything, even its records and its list of members, and knew not which way to turn.

It was then that the thought suggested itself to a few of the old friends of the Society to make an attempt to help others and to try, even if in a small way, whether the name of the Society and the standing of its officers might not be made the basis for an effort to lend a helping hand to the poor fellows who had lost their all and who would probably want to go to work again.

This effort was not a failure. We gave to those who did indeed appreciate the gift. While the better known engineers and those who occupied important positions were undoubtedly able to rehabilitate themselves, the younger men, architectural and mechanical draftsmen, surveyors and those who had the world before them, came only too gladly for help; and there is no doubt that whatever was given away,

was distributed wisely and well. At least, we tried to accomplish this object. This much in explanation of the motive that caused the Technical Society to enter upon the work of relief on a small scale.

The Society has still 160 members on its list. They are nearly all members of the Mechanics' Institute and they receive the Journal of the Association of Engineering Societies, of which this Society is a component.

The present officers are:

President — George W. Dickie.

Vice-President — Franklin Riffle.

Secretary — Otto von Geldern.

Treasurer — E. T. Schild.

Directors — Hermann Barth, H. D. Connick, Hermann Kower, Marsden Manson and Carl Uhlig.

Herewith is appended a list of those holding membership at the present time. Most of them are in good standing, and many of them have paid their dues to January, 1907.

There is good material in our Society to do effective work, and there is no reason why it should not begin its career of usefulness again. Suggested are, at this time, affiliations with other engineering societies that have been organized since the calamity. We all know how difficult it is for any society to keep up its prosperity. There are at first periods of energy followed with absolute certainty by periods of apathy, when it takes a considerable effort to keep the organization alive. It usually depends on the devotion of six or eight so-called "standby's" to hold up sufficient interest in the society until a new period of energy is brought about.

We have the advantage of the publications made by the Journal of the Association of Engineering Societies, which releases this Society from the very heavy expenditure of publishing papers. Without a current publication, an organization would sink into a lethargic condition, from which it would be impossible to revive it, and to maintain one for its individual transactions, in order to retain its specific identity, involves so great an outlay that unless the society had a very large membership, or separate means for this purpose, it would soon succumb. The past history of many of these organizations, once flourishing and active, has established this fact beyond any doubt whatever.

The Technical Society has survived all its vicissitudes since 1884, and your Secretary trusts that its sphere of usefulness may begin with renewed vigor now. It is your affair to make it do so.

In the name of the members of the Technical Society I wish to thank all those kind-hearted and thoughtful men and women who helped us when there was need for help.

I have enumerated them all, as far as I know, but if any have been overlooked, they are included among those to whom the gratitude and appreciation are due, not only from the Technical Society, but from every one who follows a technical calling, and who, directly or indirectly, derived a benefit from our efforts to help.

Respectfully submitted,

Otto von Geldern, *Secretary.*

It was moved that the recommendations made by the Secretary in his report be accepted and that he be instructed to turn over to the Mechanics' Institute Library all the books now in his charge, for the purpose of shelving them in the library building and making them available for use at once. — Carried.

Mr. Bennett moved that as many of the tools as may be needed be turned over to the Mechanics' Library, for the purpose of establishing a "*working corner*" in the library hall, for technical men, a closet to be arranged, with key, for the benefit of our members, where they may obtain drafting tools, inks, papers and office requisites for making sketches

or drawings in the library, if they should wish to do so, the librarian to arrange two or more drawing tables for this purpose.— Carried.

The Secretary was instructed to make the best possible use of what little there would be left after that, by either disposing of it among the members of the Society, or by giving it to those who may still be in need.

In the matter of the supplies, still expected from the United States Geological Survey, the Secretary was instructed to report upon the arrival of the cases, and to turn the books over to the Mechanics' Library for immediate shelving: the tape lines to be taken into consideration upon their arrival.

The Secretary was instructed to convey the thanks of the Technical Society of the Pacific Coast to every one who in the kindness of heart offered and extended help to the engineers during a period of great trial.

Voted, That these proceedings, together with the Secretary's report, be published in full in the Journal of the Association of Engineering Societies and that one hundred extra copies be struck off and distributed among the friends of the Society.

Adjourned.

Otto von Geldern, *Secretary*.

Association of Engineering Societies.

Vol. XXXVII. OCTOBER, 1906. No. 4.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, September 19, 1906. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.55 o'clock p.m., President Frank W. Hodgdon in the chair; one hundred and six members and visitors present.

The record of the last meeting was read and approved.

Messrs. Richard Gardner Hartshorne and Edward Austin Tucker were elected members of the Society.

The Secretary read a memoir of Eddy Elbert Young, a member of the Society, which had been prepared by Mr. Howard A. Carson, a committee of the Society.

On motion of Mr. Winslow, the thanks of the Society were voted to the Hon. John B. Martin, Penal Institutions Commissioner of Boston, for the use of the city steamer "Monitor," on the occasion of the trip to Deer Island this afternoon.

On motion of Mr. Kimball, the thanks of the Society were voted to Mr. E. B. Winslow, president of the Portland Stoneware Company, and to other officials of that company, for the courtesies and generous entertainment extended to members of the Society on the occasion of the trip to Portland, Me., August 3 to 5, 1906.

The discussion of the evening was on "Reinforced Concrete Construction," and was opened by Mr. Chester J. Hogue with a brief description of reinforced concrete factory construction as a type. He was followed by Messrs. L. C. Wason, J. R. Worcester and L. J. Johnson.

On account of the lateness of the hour, it was voted, on motion of Mr. L. F. Rice, to continue the discussion at a future meeting, to be held at an early date, as determined by the Board of Government.

Adjourned.

S. E. Tinkham, *Secretary.*

Boston, October 5, 1906. — A special meeting of the Boston Society of Civil Engineers was held in the library, Tremont Temple, 8 o'clock p.m.; sixty-two members and visitors present.

In the absence of the President and Vice-Presidents, Mr. J. R. Worcester was elected chairman.

The meeting was devoted to a continuation of the discussion on "Reinforced Concrete Construction," begun at the last regular meeting. Messrs. S. E. Thompson, William Parker, L. J. Johnson, L. C. Wason, C. J. Hogue, E. S. Larned and others took part in the discussion.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, OCTOBER 17, 1906. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President Frank W. Hodgdon in the chair; thirty-five members and visitors present.

The records of the last regular meeting and of the special meeting of October 5 were read and approved.

Messrs. John R. Rablin, John S. Rankin and Edward B. Richardson were elected members of the Society, and Mr. Claude A. Palmer was elected an associate.

The President announced the deaths of the following members of the Society: John E. Cheney, who died September 25, 1906, and Nelson Spofford, who died October 3, 1906; and on motion it was voted to appoint committees to prepare memoirs. The President has appointed the following as these committees: On memoir of John E. Cheney, Messrs. E. D. Leavitt, G. F. Swain and F. H. Fay; and on memoir of Nelson Spofford, Messrs. Frederick Brooks and Richard A. Hale.

The President then introduced as the speaker of the evening Mr. Charles Moore, chairman of the Board of Directors of The Submarine Signal Company, who gave an informal talk on "The Submarine Signal," which was illustrated by lantern slides. Prof. Lucian I. Blake, consulting engineer of The Submarine Signal Company, and Mr. Arnold B. Johnson, chief clerk of the United States Lighthouse Board, also gave very interesting accounts of the working of the submarine signals.

On motion of Mr. E. W. Howe it was voted: That the Society express its sincere appreciation of the courtesies extended to it by The Submarine Signal Company on the trip down Boston Harbor to inspect the operation of the submarine signal system and for the interesting illustrated description to which we have just listened.

Adjourned.

S. E. TINKHAM, *Secretary.*

SANITARY SECTION.

BOSTON, MASS., OCTOBER 10, 1906. — A regular meeting of the Sanitary Section was held at the Copley Square Hotel, Vice-Chairman Weston presiding. Forty-two members and guests were present.

A paper upon "The Relation of the Suspended Matter in Sewage to the Problem of Sewage Disposal" was presented by H. P. Eddy and A. L. Fales. The paper was illustrated with lantern slides and was discussed by Messrs. R. S. Weston, George A. Carpenter, H. W. Clark, C.-E. A. Winslow, E. B. Phelps and others.

WILLIAM S. JOHNSON, *Clerk.*

Association of Engineering Societies.

Vol. XXXVII. NOVEMBER, 1906. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, October 17, 1906. — The 621st meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, October 17, 1906. President Layman presided. Fifty-seven members and twenty-one visitors were present.

The minutes of the 620th meeting were read and approved and the minutes of the 411th and 412th meetings of the Executive Committee were read.

It was moved by Mr. Bryan, in line with the suggestion of the Executive Committee, that $100 be transferred from the General Fund to a new fund to be designated " Local Entertainment Fund," and that the present Entertainment Fund be hereafter designated " General Entertainment Fund." Mr. Robert Moore suggested that the name of the new fund be " Special Entertainment Fund." With the change in the name suggested by Mr. Moore the motion was carried.

The application for membership in the Club of Alfred George Shutt was presented.

Mr. Edwin Dwight Smith was elected to membership in the Club.

Owing to the illness of Mr. Zeller, chairman of the Committee on Membership, and to the absence from the city of Mr. McCulloch, a second member of the committee, the President of the Club suggested that Mr. Bryan act as temporary chairman of the committee and that the Chair be given power to appoint two assistants to Mr. Bryan, to serve during the absence of Mr. Zeller and of Mr. McCulloch. The suggestion of the President was approved by the Club.

A meeting of more than ordinary interest resulted from the spirited and efficient discussion of the " bridge situation," by the following gentlemen: Messrs. Robert Moore, Albert T. Perkins, consulting engineers to the Terminal Railroad Commission; Julius Pitzman; M. L. Holman; Edward Flad; Geo. Hannauer, superintendent Wiggins Ferry Company; H. J. Pfeifer; R. S. Colnon; S. Bent Russell; R. H. Phillips; P. M. Bruner.

Owing to the unusual interest manifested, the hour was late when the meeting adjourned.

R. H. Fernald, *Secretary.*

St. Louis, November 7, 1906. — The 622d meeting of the Engineers' Club of St. Louis was held in Memorial Hall, Museum of Fine Arts, 19th and Locust streets, St. Louis, on Wednesday evening, November 7, 1906, at eight o'clock. President Layman presided. There were present about sixty members and between two hundred and fifty and two hundred and seventy-five visitors.

The meeting was an "open" meeting, and many friends, including a large number of ladies, responded to the invitation of the Club.

Promptly at eight o'clock President Layman called the business meeting to order. Upon motion of Mr. Brenneke the last five past-presidents were appointed as a nominating committee for the nominating of officers for the next year. The five gentlemen elected were Messrs. Edward Flad (chairman), J. A. Ockerson, J. L. Van Ornum, J. H. Kinealy and E. J. Spencer.

The President announced the following committees on resolutions:

On the death of Mr. Wm. Wise: Robert McMath, chairman; Robert Moore, M. L. Holman. On the death of Mr. A. H. Zeller: Edward Flad, chairman; W. G. Brenneke, R. H. Fernald.

The formal business meeting then adjourned.

At 8.30 o'clock the President introduced the speaker of the evening, Mr. Richard L. Humphrey, member American Society of Civil Engineers; consulting engineer, secretary National Advisory Board on Fuels and Structural Materials. Mr. Humphrey's lecture on the San Francisco earthquake was of unusual interest, and the profusion of excellent lantern slides brought the conditions on the Pacific Coast very near to all who were fortunate enough to be present.

At the close of the lecture the galleries of the Museum of Fine Arts were thrown open for an informal reception.

A hearty vote of thanks was extended by President Layman to Mr. Humphrey for his interesting and instructive lecture.

Adjourned.

R. H. Fernald, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., November 21, 1906. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President Frank W. Hodgdon in the chair; fifty-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. Raymond C. Allen and George E. Harkness were elected members of the Society.

The President announced the death of Freeman C. Coffin, Senior Vice-President of the Society and chairman of the Sanitary Section, which occurred November 11, 1906.

On motion of Mr. French, the President was requested to appoint a committee to prepare a memoir. The President appointed the following members as that committee: Leonard Metcalf and William S. Johnson.

The Secretary read a letter from Dr. Clarence J. Blake, presenting to the Society a set of 13 volumes of the Pacific Railway Surveys as a memorial of his father, John H. Blake, first secretary of the Society.

On motion of Mr. Brooks, the officers of the Society were directed to express to Dr. Blake the thanks of the Society and its appreciation of his valuable gift.

The President then introduced Mr. Frederic A. Kummer, chief engineer United States Wood Preserving Company, who read a paper on "The Development of Wood Pavements." The paper was illustrated with lantern slides.

Mr. A. L. Plimpton, with the aid of a large diagram, explained the method used in laying the street railway track in Washington Street.

On motion of Mr. Manley the thanks of the Society were voted to Mr. Kummer and the company which he represented for the very interesting paper which he had just read, and for the courtesies extended to the Society this afternoon on the occasion of the excursion to examine the wood pavement being laid on Washington Street.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., November 10, 1906. — The regular meeting for November, 1906, was called to order in the Society room, 225 North Main Street, Saturday evening, November 10. After waiting for some time and no quorum appearing, the meeting was adjourned to Saturday evening, November 17, 1906.

Clinton H. Moore, *Secretary.*

Butte, Mont., November 17, 1906. — The adjourned November meeting of the Society was called to order on the above date at 8 p.m., in the Society room, 225 North Main Street. Quorum present. President Dunshee presided. Minutes of last two meetings read and approved. Application for membership by Fred J. Brule read and approved and ballots for same ordered circulated. Geo. A. Griggs and Sedman W. Wynne elected to membership by a unanimous vote. It was decided to hold the next annual meeting in Butte, January 10, 11, 12, 1907, and the following Committee on Arrangements was selected: Messrs. Moulthrop, McArthur, Barker, Dunshee and Moore. Committee on Nomination of Officers for next year presented the following names:

President — Edward C. Kinney.

First Vice-President — Archer E. Wheeler.

Second Vice-President — Arthur H. Wethey.

Secretary and Librarian, Clinton H. Moore.

Treasurer and Member of the Board of Managers of the Association of Engineering Societies — Sam'l Barker, Jr.

Trustee — Azelle E. Hobart.

Signed — C. W. Goodale, Eugene Carroll, Geo. E. Moulthrop, Committee.

The Committee on Resolutions on the death of Thos. T. Baker reported the following:

Whereas, In the death of Thomas T. Baker the Montana Society of Engineers has suffered a great loss, and desiring to place on record its

appreciation of his high character, both as an engineer and a man, and of his tireless energy displayed in helping to build up the state of Montana for the past forty years; therefore be it

Resolved, That we tender to his bereaved family our sincere sympathy, and that a copy of these resolutions be spread on the minutes of this Society and another be sent to the family of the deceased.

A. E. Hobart,
Samuel Barker, Jr.,
Robert A. McArthur,
Committee.

Adopted.

On application, Edward K. Triol was transferred to the class of corresponding members. The Secretary called the attention of the members to several new works, gifts to the Society, and he was instructed to acknowledge the receipt of the same.

Adjourned.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, November 9, 1906. — Regular meeting called to order at 8.30 p.m.

The minutes of the last regular meeting of October were read and approved.

The members discussed in various ways the plan of a future activity for the Society, and concluded to take up the structural work in the rehabilitation of San Francisco as one of the most important engineering subjects at the present time.

The Secretary was instructed to write to a number of engineers who make a specialty of reënforced concrete construction, requesting their coöperation in this matter by the contribution of papers, leading to a general discussion of this important work.

The following names were suggested: Prof. C. B. Wing, Stanford University; Prof. C. Derleth, Jr., University of California; Mr. M. C. Couchot, San Francisco; Mr. C. F. Wieland, San Francisco; Mr. L. A. Hicks, San Francisco; Mr. J. C. Bennett, San Francisco.

The Secretary thereupon drew up the following program for the meeting to be held on December 7, 1906, which was subsequently approved by the Executive Committee.

Technical Society of the Pacific Coast. Mechanics' Institute.

The next regular meeting of the Society will be held on Friday evening, December 7, at eight o'clock, in the hall of the Mechanics' Library, 99 Grove Street, on the old Pavilion site.

The evening will be devoted to the discussion of the important subject of "Reënforced Concrete Structures."

The following contributions have been communicated to the Secretary and will be brought up:

1. "The Mechanics of Reënforced Concrete." By Prof. Charles B. Wing.
2. "The Long Beach Hotel Accident." By Lewis A. Hicks.
3. "Designs of Buildings under Construction." By C. F. Wieland.

On similar subjects that have not been announced by title to the Secretary in time for this notice, the following gentlemen have indicated their willingness to contribute: Prof. Charles Derleth, Jr., Mr. M. C. Couchot, Mr. Jas. C. Bennett.

The Technical Society desires a full gathering of all its members, in order to lay out a plan for future work. It has the men and it should create the opportunity.

It is a part of the program to make the arrangements for the usual semi-annual dinner, and the committees will be appointed to take this matter in hand.

Members and their ladies contemplate holding a reunion to exchange greetings for the first time since the catastrophe, and in order to make the necessary arrangements for this a full meeting is desirable.

A Nominating Committee will be appointed to select a ticket of officers for the ensuing year.

This notice is an invitation to any one who may receive it. All who are interested in technical subjects are cordially invited to attend this meeting, whether members of the Society or not.

Inspect the new technical books that have been placed on the shelves and purchased by the Mechanics' Library.

All members are urgently requested to be present.

Meeting adjourned.

Attest:

OTTO VON GELDERN, *Secretary.*

Association

of

Engineering Societies.

Vol. XXXVII. **DECEMBER, 1906.** No. 6.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, November 21, 1906. — The 623d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, November 21, 1906. President Layman presided. Thirty-three members and thirty visitors were present.

The minutes of the 621st and of the 622d meetings were read and approved, and the minutes of the 413th meeting of the Executive Committee were read.

Mr. Alfred George Schutt was elected to membership in the Club.

Applications for membership were presented from August Emanuel Bjork, Daniel Breck, Francis E. Schwentler, Eugene Tritle Spencer.

A letter from Mr. Albert T. Perkins, expressing his appreciation of the courtesy extended to him by the Club, was read by the Secretary, and also a letter stating that Mr. Selden could not be present to participate in the evening's discussion as had been hoped.

The President announced the Committee on Extension of Membership to be Messrs. W. H. Bryan (chairman), W. H. Henby, H. C. Toensfeldt.

Upon motion of Mr. Brenneke the Executive Committee was instructed to make the proper arrangements for the annual dinner of the Club.

The committee appointed for nominating officers for 1907 presented the following report:

St. Louis, November 20, 1906.

To the Engineers' Club of St. Louis, St. Louis, Mo.:

Gentlemen, — Your Nominating Committee submits herewith the names of candidates selected for the various offices for the ensuing year:

President — Mr. E. R. Fish.
Vice-President — Mr. W. G. Brenneke.
Secretary and Librarian — Mr. R. H. Fernald.
Treasurer — Mr. E. E. Wall.
Directors — Mr. R. S. Colnon and Mr. Richard McCulloch.
Members of the Board of Managers of the Associated Societies — Mr. A. P. Greensfelder and Mr. R. Lincoln Murphy.

Respectfully submitted.

(Signed) J. A. Ockerson,
J. L. Van Ornum,
J. H. Kinealy,
E. J. Spencer,
Edw. Flad, *Chairman*,
Committee.

Owing to the absence of Mr. McMath the Committee on Resolutions on the death of Mr. William Wise was unable to report at this meeting.

The report of the Committee on Resolutions on the death of Mr. A. H. Zeller was presented by Mr. Flad. The report was ordered spread on the records of the Club, and copies of the report were ordered sent to the members of the family and to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for publication.

Letters from Mrs. F. C. Case, daughter of Mr. William Wise, and from Mr. William F. Zeller, brother of Mr. A. H. Zeller, were read, expressing their appreciation of the action of the Club at the time of the deaths of Mr. Wise and Mr. Zeller.

Upon motion of Mr. Brenneke the Executive Committee was instructed to make a report on the question of honorary membership, as it is felt by some that the present section of the constitution relating to the subject is not what it should be.

The discussion of the evening upon "Structural Lessons from the San Francisco Fire and Earthquake" was opened by Prof. J. L. Van Ornum, who illustrated his paper upon the subject by appropriate lantern slides.

The discussion was instructive, spirited and concise, the following gentlemen having prepared especially for the evening's program: W. H. Bryan, A. O. Cunningham, E. B. Fay, R. L. Murphy, H. C. Toensfeldt and Richard L. Humphrey of the structural materials department of the government testing plant.

A valuable addition to the discussion, as well as to the general pleasure of the evening, was contributed by a guest, Prof. K. E. Hilgard, C. E., of Zürich, Switzerland, who was formerly president of the Civil Engineers' Society of St. Paul, and bridge engineer for the Northern Pacific. Professor Hilgard extended a cordial invitation to the members of the Engineers' Club of St. Louis to present themselves at the headquarters of the society in Zürich, of which he is now president.

Adjourned.

R. H. FERNALD, *Secretary.*

The Civil Engineers' Club of Cleveland.

REGULAR MEETING, OCTOBER 9, 1906, at the Club rooms, called to order by the President, at 8.15 P.M. Present, thirty-nine members and ten visitors.

Minutes of two preceding meetings read and approved.

Applications for active membership of E. Williams Dennison, Claude F. Mullen and William H. Parish, approved by the Executive Board, were read.

The tellers reported the election to active membership of George Lyman Grimes, Thomas Seth Kemble and Burt Raymond Weidenkopf; and a tie vote on the proposition to discontinue the subscription to the JOURNAL and membership in the Association of Engineering Societies (23–23).

The Secretary read a letter from Mr. F. H. Richards, a corresponding member, strongly urging the continuance of the present arrangement as

to the Association of Engineering Societies, together with a circular letter from Mr. Fred. Brooks, Secretary of the Association, outlining his plans for the JOURNAL and requesting papers for publication.

Mr. Lane moved that the Club's subscription to the JOURNAL be reduced 50 per cent. (no second). Mr. Green moved that the Executive Board be given authority to reduce subscriptions 50 per cent. if in its opinion it could be done without detriment to the Club, and if it could find means of apportioning the remaining subscriptions equitably. Carried.

On motion of Mr. Green an informal rising vote was taken: First, as to how many wished to retain the JOURNAL as at present; and second, as to how many would be willing to pay $1.00 over and above the present dues for the privilege of retaining the JOURNAL. On the first proposition the vote was twelve for and twenty-five against retaining the JOURNAL. On the second proposition the vote was fifteen in favor of paying $1.00 extra and twenty-two against. The Secretary presented a verbal report of a special committee of the Executive Board on amalgamation with the Electric Club, stating that the Committee had attended the meeting of that Club on the 3d inst., and that it had had a meeting since with a similar committee of the Electric Club, appointed at that meeting, and had agreed in a general way on the terms of such an amalgamation, which were to be stated in a proposition to be submitted by the Electric Club to the Civil Engineers' Club. Mr. E. P. Roberts, President of the Electric Club, was then given the floor and submitted a formal proposition.

On motion of the Secretary this was referred to the existing committee, with authority to prepare a letter ballot, to be canvassed at the next meeting of the Club, if possible, setting forth in detail the terms of the proposition. Resolutions on the death of Mr. Charles Paine, first president and an honorary member of the Club, prepared by Messrs. Rice, Burgess and Paul, as a committee, were read by the Secretary and adopted. The paper of the evening, describing the evolution of ore and coal-handling machinery along the lakes, and illustrated by lantern slides, was read by Mr. C. H. Wright, who humorously called his subject "Pork," having in mind the southern hotel keeper who kept a supply of salt pork always on hand for use should he fail to get anything else to serve his guests.

After adjournment lunch was served.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

REGULAR MEETING, NOVEMBER 13, 1906, at the Club rooms, called to order by the President at 8.15 P.M. Present, forty-five members and visitors.

Minutes of the preceding meeting read and approved.

The applications for active membership of Harold Bentley Anderson, Carroll Wilder Brown and John Elmer Linabury, approved by the Executive Board, were read.

It was announced that Mr. Cox has requested to be relieved of the chairmanship of the New Quarters Committee and that the President has appointed Mr. Wright in his place.

A letter from Mr. N. T. Harrington was referred to, in which he ex-

pressed himself willing to enlarge the paper read before the club at the January meeting, "Suction Gas Producers for Power Purposes," and prepare same for publication in the JOURNAL. Mr. Harrington had been requested to do so, in response to an appeal from Mr. Fred. Brooks, Secretary of the Association of Engineering Societies, for new material for publication in the JOURNAL, to which the paper of the evening is expected to serve as a further contribution.

The tellers, Messrs. Ullmer and Daniels, reported the election to active membership of E. Williams Dennison, Claude F. Mullen and William H. Parish.

Mr. Chas. H. Wright reported in behalf of the committee on the amalgamation of the Electric Club with the Civil Engineers' Club (which committee coöperated with a similar committee appointed by the Electric Club), stating that although terms had been agreed upon as per signed memorandum of agreement attached, and although the committee had followed instructions received at the last meeting and prepared a ballot on the question, which was printed and all ready to be mailed to the members, so as to be canvassed at this meeting, it was deemed advisable to withhold this ballot indefinitely and to drop the matter until the Electric Club take action warranting the canvassing of this ballot. The committee arrived at this decision after learning that the Electric Club at the last meeting has set aside the vote it canvassed, which resulted in an expression in favor of the amalgamation and decided to lay the matter on the table indefinitely pending the preparation of amendments to the constitution covering the question of amalgamation or disbanding.

Mr. Horner voiced the Club's sentiments in indorsing the committee's decision relative to taking no further action until the Electric Club decides on something definite.

The President announced that the report of the New Quarters Committee, presented at the last meeting of the Executive Board, has been accepted and the committee instructed to report at this meeting for final action.

Mr. Wright, the chairman of this committee, accredited Mr. Allen with doing the largest share of the work of the committee, and stated that quarters in a number of buildings have been inspected and that, considering location, price, adaptability for clubroom purposes, a suite of rooms 714–719 inclusive in the Caxton Building commends itself as the most favorable. These quarters, covering an area of 2 000 sq. ft., as against 1 500 sq. ft. in the present quarters, can be secured at a rental price of $1 200 per annum for the first year and $1 320 for the two subsequent years of a three-year lease. The rooms lend themselves better for a desirable division into assembly room, library, billiard and pool-room than other rooms inspected or the present quarters.

These rooms can be occupied by about the first of the year and no rental will be charged before April 1, 1907, unless the lease on the present quarters can be disposed of before that time, which marks the expiration of the Club's arrangement with the Associated Technical Clubs.

To allay the fears of some members relative to elevator service, the committee was assured that ordinarily elevators run until 10 P.M., but that on nights when the Club holds meetings the service will be extended till 11 or 12 P.M., if necessary. The committee received the further

promise that the partitions are to be changed to suit the wishes of the Club; likewise the decorations, including the lighting fixtures.

The committee further recommends that the Club close the lease in its own name and that the Club duly consider the raising of the necessary money to meet the rental, which is higher than the Club's contribution to the Associated Technical Clubs.

The President supplemented the report by stating that the Executive Board expects to cut down the subscription to the JOURNAL by 50 per cent., which will mean a saving of approximately $400 per year, and this, added to the Club's share in the present arrangement on quarters (approximate $1 000), will more than equal the rental price of the new quarters. For this reason the Executive Board voted to accept the proposition from the Caxton Building Company, without awaiting the action of the other clubs.

After a brief discussion a motion was made by Mr. Lane and seconded by Mr. Nelles to accept the report of the New Quarters Committee, to close the lease for the quarters in the Caxton Building referred to and to move as soon as arrangements can be completed.

This was unanimously carried.

Following a brief discussion on the Club's relation to the other three clubs sharing the quarters, a motion was made by Mr. Wright and seconded by Mr. Nelles that the Club withdraw from the arrangement with the Associated Technical Clubs at the expiration of the term of agreement and that the Secretary notify these clubs of the action and extend to them an invitation to move with the Club as its tenants.

Motion unanimously carried.

Mr. Hanlon, as chairman of the Grade Crossing Committee, sent in a telephone message referring to the report made at the February meeting, and stating that his committee is not prepared to submit a final report until a later meeting.

After some discussion Mr. Lane made a motion that the Club recommend not to allow any overhead crossings with clearance less than 21 ft. and that the committee be continued to further investigate the subject.

Carried.

A letter from General Smith, chairman of the High Level Bridge Committee, was read promising a report from his committee for the next meeting and explaining why the committee had not reported before.

Professor Benjamin, chairman of the Building Code Committee, sent word that the work of his committee would be reported on by either Mr. McGeorge or Mr. Barnum. Neither of the gentlemen being present the report was not received.

No reports were received from the Water Pollution Committee, Committee on Code of Ethics and Scale of Fees, or City Dock Improvement Committee.

The paper of the evening was read by Mr. Geo. Velten Steeb on the subject of "Fire Protection Engineering" and was followed by a very interesting discussion, in which the President, a number of members and visitors participated.

On motion of Mr. Palmer the Club extended a vote of thanks to Mr. Steeb for his valuable paper and willing services to the Club.

Adjourned.

DAVID GAEHR, *Acting Secretary.*

Regular Meeting, December 11, 1906, at the Club rooms, called to order by the Vice-President at 8.00 p.m. Present, thirty-two members and four visitors. Minutes of preceding meeting read and approved.

Application for active membership of Clarence W. Courtney, approved by the Executive Board, was read. The tellers, Messrs. W. M. Allen and H. M. Lucas, reported the election to active membership of Messrs. Harold Bentley Anderson, Carroll Wilder Brown and John Elmer Linabury; and a unanimous vote in favor of transferring $750.00 from the Permanent to the General Fund.

The Secretary submitted a brief verbal report of progress from the House Committee, stating that two of the three clubs in the Association had signified their intention of becoming tenants of the Civil Engineers' Club in the new quarters; and that the moving would probably take place about January 1, next.

The paper of the evening was a description of the dock extension work of the Lake Shore & Michigan Southern Railroad during the past season at Ashtabula Harbor, by Mr. Rote. An extended discussion followed, taken part in by Messrs. Nelles, Gaehr, Perrine, Wright and others.

Adjourned.

Joe. C. Beardsley, *Secretary.*